Industrial QUALITY CONTROL

MAY, 1952 VOL. VIII NO. 6

Onondaga County War Memorial Auditorium—Site of Sixth Annual ASQC Convention

CONVENTION ISSUE

Convention Headquarters:
War Memorial Auditorium

CONTENTS PAGE 19
PROGRAM PAGE 83

Information Desks:
War Memorial Auditorium
Hotels Syracuse and Onondaga

AMERICAN SOCIETY FOR QUALITY CONTROL

The *Sheffield* Precisionaire is an all-around gage

The Sheffield Precisionaire Gage is equally applicable to all phases of inspection—receiving, tool room, process, quality control and final. Practically any dimension or relationship between elements can be measured.

It is ideal for guiding the individual machine operator in preventing scrap loss. It may be used as a comparator. Also, because of its linear scale, it gives precisely the value of the dimensions being measured so that parts may be classified in size ranges. This assures greater accuracy and faster assembly.

The work may be presented to the gage, or the gaging element at the end of a flexible tube may be presented to the work at any distance from the base instrument without loss of accuracy or gaging speed.

The wide range of amplifications from less than 1,000 to more than 100,000 to 1 provides an adequate choice to meet any set of gaging requirements.

Call your local Sheffield representative or write for Bulletin CTP-491 which gives complete specifications.

the *Sheffield* corporation

Dayton 1, Ohio, U.S.A.

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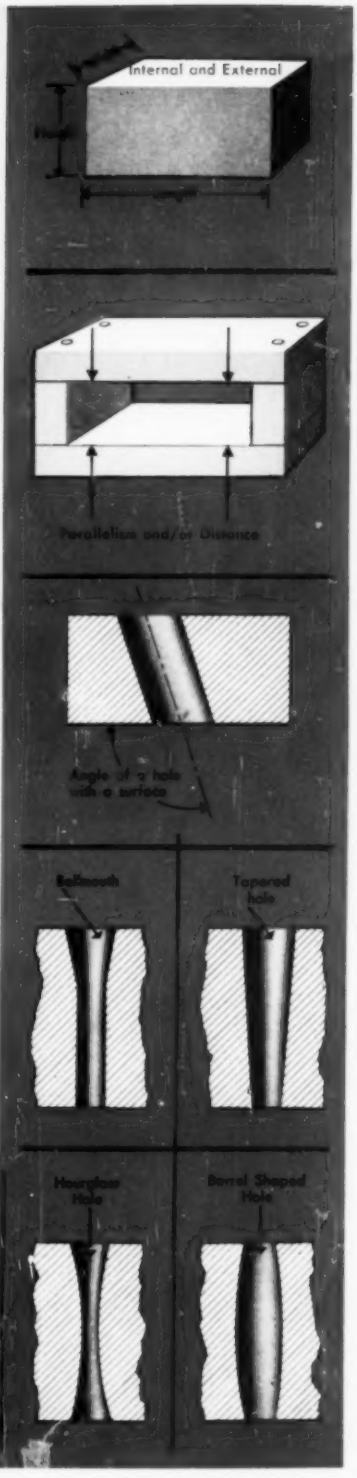
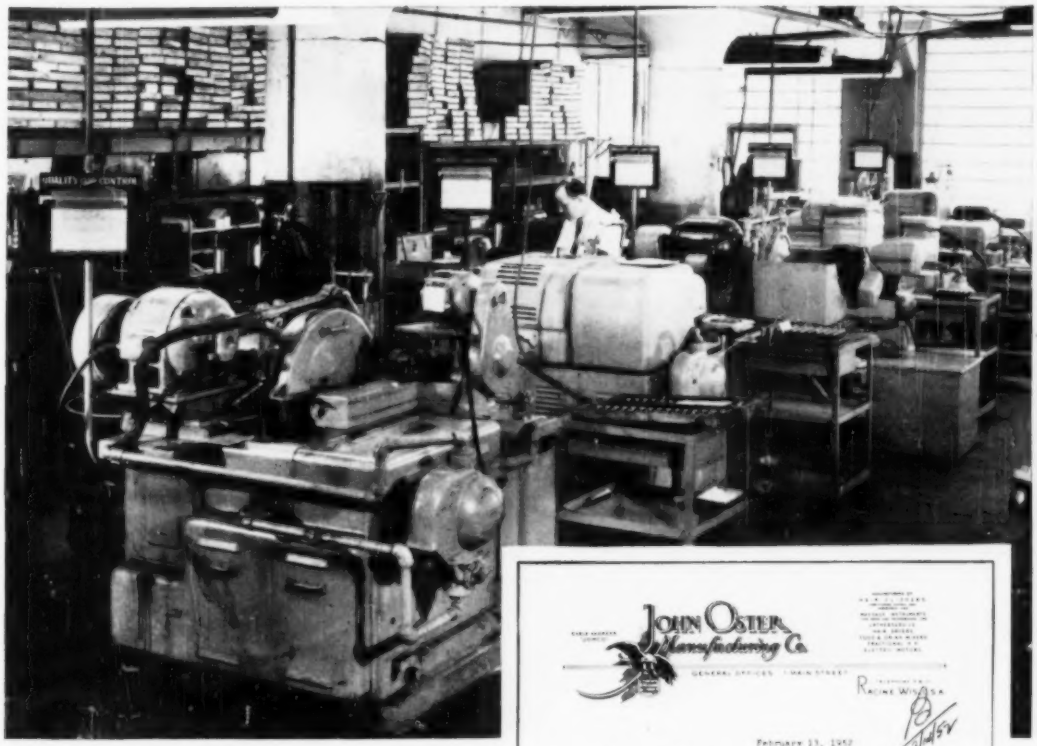
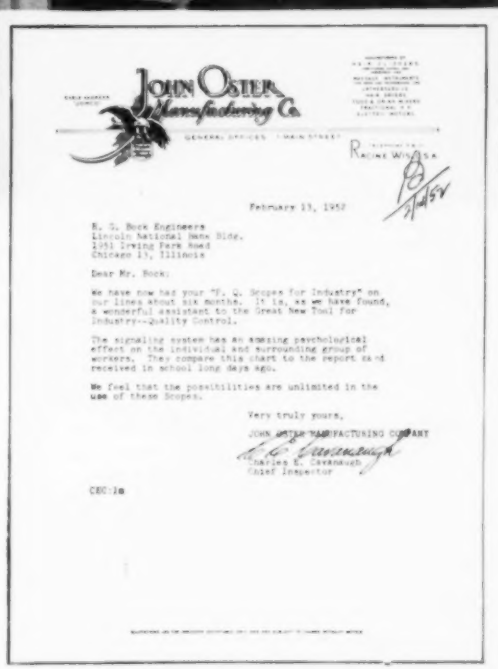


The JOHN OSTER *Manufacturing Co. of Racine, Wisconsin*

Use **R. G. BOCK P. Q. SCOPES** to help them maintain their high standards of quality





JOHN OSTER Manufacturing Co.

GENERAL OFFICES — MAIN STREET

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February 13, 1952

R. G. Bock Engineers
Lincoln National Bank Bldg.
1951 Irving Park Road
Chicago 13, Illinois

Dear Mr. Bock:

We have now had your "P. Q. Scopes for Industry" on our lines about six months. It is, as we have found, a wonderful assistant to the Great New Tool for industry--Quality Control.

The signaling system has an amazing psychological effect on the individual and surrounding group of workers. They compare this chart to the reports card received in school long days ago.

We feel that the possibilities are unlimited in the use of these Scopes.

Very truly yours,

JOHN OSTER MANUFACTURING COMPANY

Charles E. Cavanaugh
Chief Inspector

CEC:le

THE QUALITY INDEX — Standard Conformity

The **Quality Index**, developed by R. G. Bock Engineers, is a scale of values for measuring quality levels of Processes, Products, Operators, Groups, Departments, and the entire Plant, rating evaluations with equal clarity to the average worker or supervisor — as to management, engineering, or to the quality control group, **it provides a Uniform Method for rating Quality.**

Upper and lower control limits are established at 100 S. C. (standard conformity), and the mean at 130 S. C. The Quality Index corresponds with Standard Deviation—three sigma range. Plottings within control limits are signaled in green; out of control in red, showing magnitude of variations. **The Quality Index is adaptable with any type of control chart** and coordinates the control chart with the signal arm of the R. G. Bock P. Q. Scope. **Write for our new Outline of Practice release.**

R. G. BOCK P. Q. SCOPE provides for (1) measuring (2) recording (3) signaling productivity and/or the statistical quality level of a process. Excercises an added alerting influence upon operating personnel by bringing below standard performance into focus for corrective action, **while a job is running.**

Order direct from **R. G. BOCK ENGINEERS** *INDUSTRIAL MANAGEMENT*

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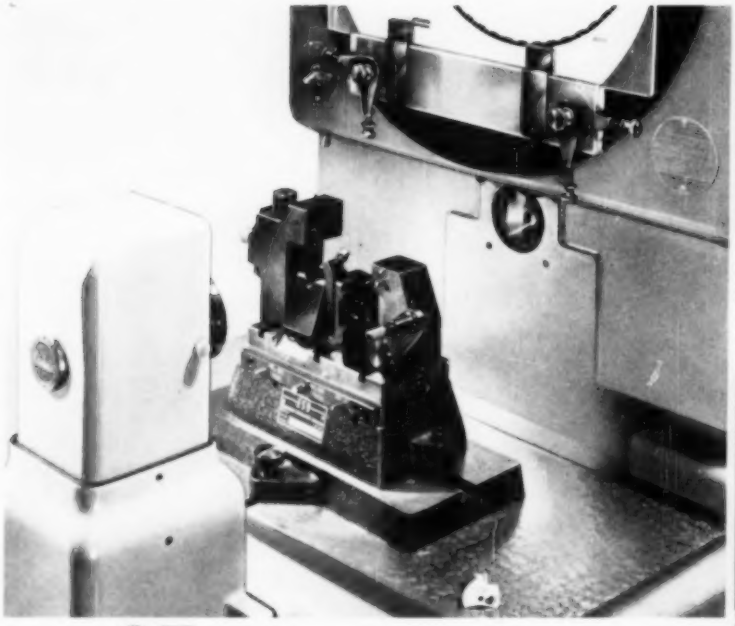
Industrial Quality Control is published bi-monthly by the American Society for Quality Control, Inc. Entered as second class matter September 18, 1950, at the Post Office at Milwaukee, Wisconsin. Yearly subscription $3.00, non-members $6.00. Office of publication, 239 East Chicago Street, Milwaukee, Wisconsin. Headquarters office, 70 East 45th Street, New York 17, New York.



27 GAGES combined into *One!*

OPTICAL Projection Gaging has made possible a saving in gaging costs of over 500% on the small ROTOR part shown in the lower right corner of the above photo.

Twenty seven mechanical gages, and as many gaging operations, were formerly required to check the critical dimensions of this high production part. These 27 mechanical gages have been replaced by ONE PROJECTION GAGE and coordinated Chart-Gage Screen. Inspection time has been reduced from 4 minutes per part to 40 seconds.

Many Industries and Government facilities have experienced similar savings in their inspection costs when using Optical Projection Gaging.

Send us sample parts and specification prints for our analysis of how Optical Projection Gaging can help you or write and have our local representative contact you for personal conference.

Visit our Booth 5-6 at the Quality Control Convention in Syracuse, N. Y., May 22 - 24.

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ENGINEERS SPECIALTIES DIVISION

THE UNIVERSAL ENGRAVING & COLORPLATE CO., INC.

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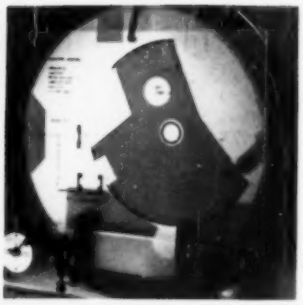
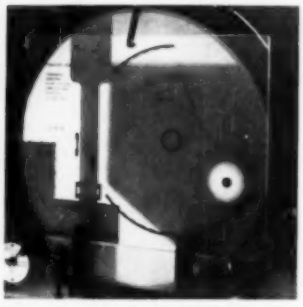
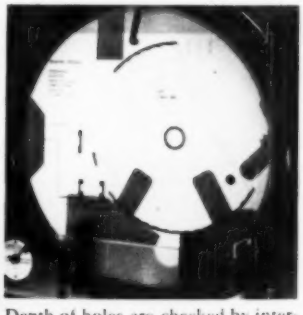


8 dimensions plus concentricity are checked to go and no-go limits on coordinated Chart-Gage Screen.

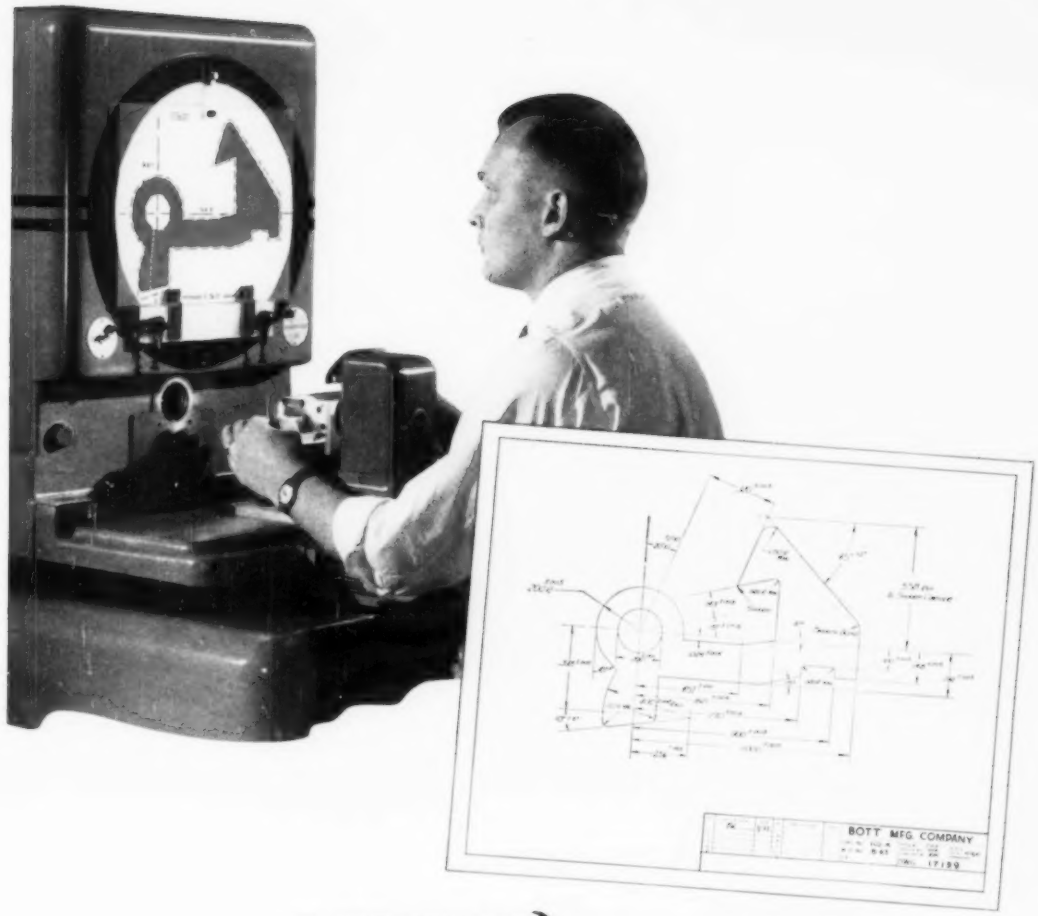


Hole location and straightness are checked by interposer Pin to Micro Gage tolerance line.

Interposer checks part thickness and counter bore depth to micro-gage tolerance line on chart.



Depth of holes are checked by interposer pin shown at top to tolerance limit lines on Chart.



He checks 15 DIMENSIONS 8 RADII 7 ANGLES } in ONE operation

To check this part completely and accurately by usual methods, you might need as many as two dozen or more different gages—and you still wouldn't be sure all corners were sharp, all angles and radii exact. There's a much faster, more accurate way to do the job completely, one that requires no mechanical gages that can lose accuracy through wear.

On the Kodak Contour Projector, Model 3, you just slip the part into a holding fixture and compare its magnified image with a "chart-gage" over the bright screen. *Every* detail shown on the drawing is quickly and directly compared against the part itself, to close tolerances and in *one* operation. Little training or experience is required.

The part we show here is a relatively simple one for an optical comparator. With proper fixtures, charts, and accessories, you can measure all sorts of complex parts, large or small. Changes in specifications generally require nothing more than a corresponding change on the chart.

So overwhelmingly has industry turned to optical gaging that production of the Kodak Contour Projector, Model 3, the outstanding instrument for this method, has been greatly accelerated. Deliveries are rapid, and the cost of projector, fixture, chart-gages, and accessories usually comes below corresponding sets of mechanical gages. To get an idea of the large labor savings that the Kodak Contour Projector can bring to your inspection problems, get in touch with Eastman Kodak Company, Industrial Optical Sales Division, Rochester 4, N. Y.

the KODAK CONTOUR PROJECTOR

If you want to check precision spur and helical gears in action, write for information about Kodak Conju-Gage Instrumentation.

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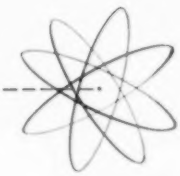


TO CLOSE

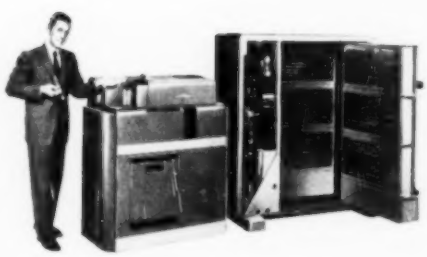
QUALITY CONTROL

IBM *Electronic Business Machines*

Increased production . . . new production techniques . . . material scarcities—all emphasize the *vital* need for the precise statistical quality control made possible by IBM Electronic Machines.

Electronic tubes enable these machines to process huge quantities of statistical and mathematical data at speeds unprecedented in industry. They calculate arithmetic means, variance, and control limits; they perform correlation studies to determine variables affecting quality; and they do many other equally important quality control jobs.

With this versatile IBM electronic equipment at its command, industry has at its fingertips data relating to every phase of quality control.



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You can still have a kit of our current Quality-Cost displays. Simply drop us a line on your company letterhead. There is no obligation.
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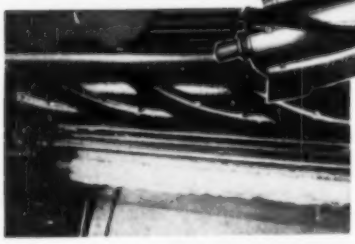

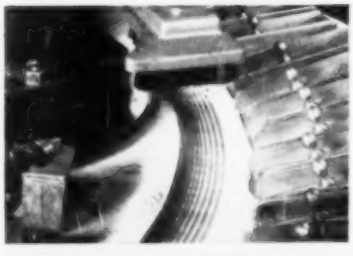

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Whatever your primary consideration — quality, price, or any other factor — you can get exactly what you want in Fullergript power-driven brushes.

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It will pay you to investigate the possibilities of Fullergript for your own plant.

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3 *NEW* Basic Aids to QUALITY CONTROL:

❶ PAR-AC Electronic Production Gage

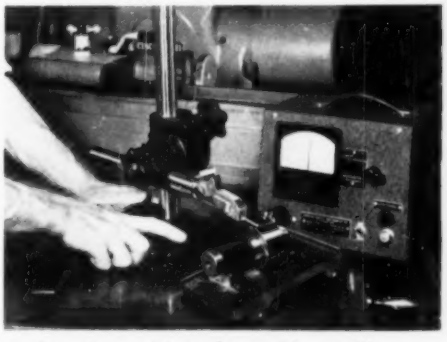
For high-precision repetitive gaging of one or more dimensions. Reads .00001" and .0001" or .00005" and .0005" per scale division. Provides the *dependable, numerical data* required for statistical quality control—right at the machine if desired—as quickly as parts can be placed beneath the gage head.

❷ MICRO-AC Electronic Microcomparator

For checking dimensions DIRECTLY IN MILLIONTHS. Designed specifically for gage room use and for ultra-precision production gaging. Reads .000001" and .000010" per scale division. Gives a fast, accurate check of gage blocks and master gages—the standards of measurement that govern the accuracy of every dimensional-control system.

❸ INDI-AC Electronic Indicator

A portable, high-precision instrument for checking set-ups and runout on the machine, and for surface-plate work in the shop, toolroom or gage room. Reads .00001" and .0001" or .00005" and .0005" per division.



ALL 3 INSTRUMENTS Offer These OUTSTANDING ADVANTAGES:

- CONSISTENT REPEAT READINGS, because of *drift-free amplifier* and *frictionless gage head movement.*
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- CONTINUOUS LINEAR SCALES, both sides of same zero. The two scales always give the same reading, and can be used interchangeably at will.
- MEASUREMENT RECORDING. A pen recorder may be used with these instruments and the inked tape kept as a record of the measurements.
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Automatic Screw Machines from 1/8" to 1 1/2"

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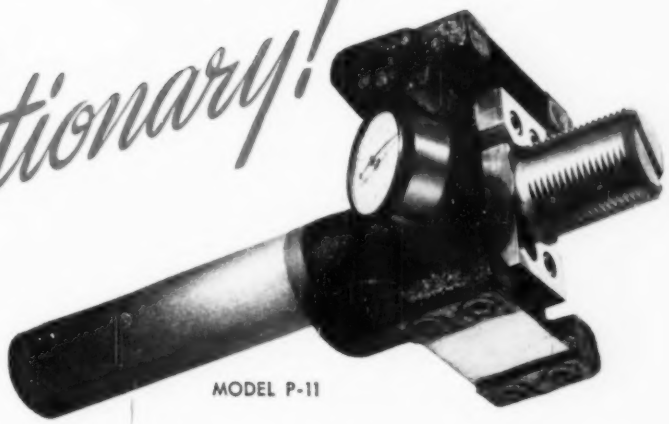

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no other gage can tell so much— so fast—about internal threads

The P-11 Internal Thread Gage gives one accumulated reading of P. D., form and lead. Variation of these elements from basic size is shown on the dial indicator which reads in .0005". Interchangeable pairs of segments inspect all classes of internal threads from 5/16" to 5" dia. The segments work on the principle of an expanding master plug. This 14 oz. portable gage is designed for use in the shop or at the inspection bench. Descriptive literature on this gage and other Bryant gages is available on request. Send coupon today.

Bench type gages for external or internal threads are available, with or without squareness-of-face attachment.

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BRYANT CHUCKING GRINDER CO., SPRINGFIELD, VT.

Please send me illustrated folders giving full information on the Bryant Portable and Bench Thread Gages.

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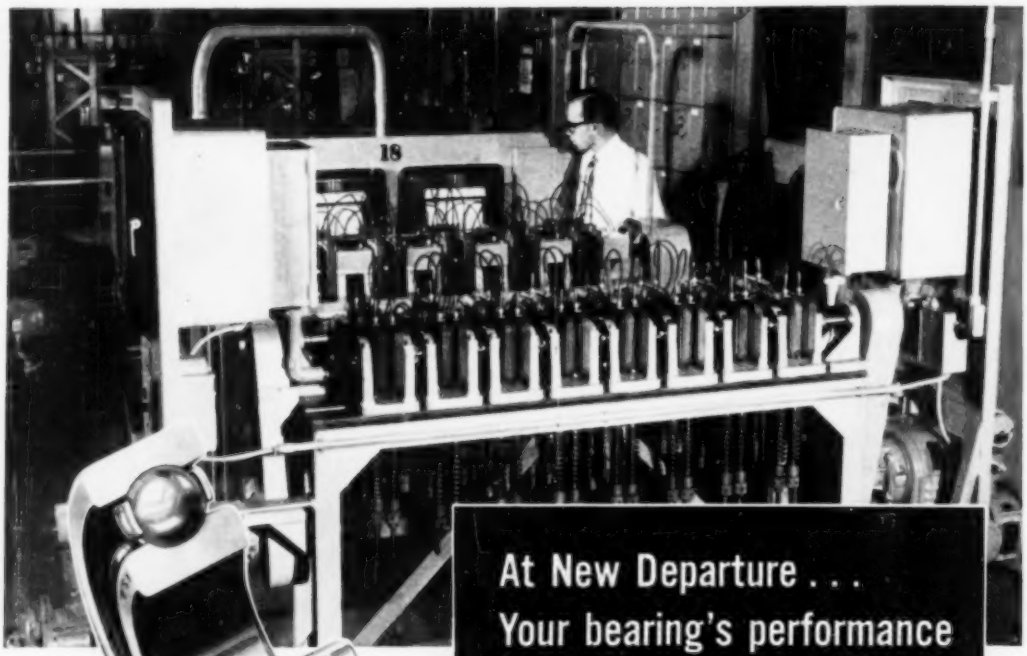

At New Department . . . Your bearing's performance is tested and proved *before* you use it

Considering the big part ball bearings must play in the efficient operation of your machine, it is important for you to *know*, and in *advance*, how the bearings will perform.

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Supplying you with this information is just one of the functions of New Department's new and ultra-modern engineering laboratory.

To help you get the answers:

What is the determining factor of seal-bearing life?

How operating conditions contribute to metal fatigue?

Which has the most effect on grease life—speed or load?

Lubrication selection.

. . . a monograph, "Grease Lubrication of Ball Bearings," by New Departure's Manager of Research, Development and Design, will be mailed upon request.

163

Nothing Rolls Like a Ball . . .

NEW DEPARTURE
BALL BEARINGS

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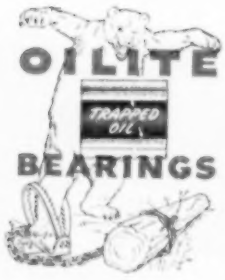

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Let's talk "Nuts and Bolts"

Small talk, some may say. But they'd be wrong.
For to us in industry, to talk "nuts and bolts" is to
discuss the basic design and construction of a product.
And we do a lot of that at John Deere.

But even though it were taken literally, it still wouldn't
be small talk—not to us, anyway. Because anything and everything
that goes into John Deere equipment is an important subject
around here. That, of course, grows out of the well-known
John Deere policy of building Quality into everything that bears the name.

Naturally, maintaining such a policy calls for a lot more
than talk. That is why a corps of skilled specialists who are
also practiced skeptics—men who know metals and all their
characteristics and who are willing to take nothing for granted—
check constantly to make sure that every part measures up to the high
standard of serviceability farmers have come to expect of John Deere
equipment. As part of a practical Quality Control Program,
they apply test after test at every stage of manufacturing,
from that of raw material to that of finished product.

Then, and only then, does a piece of equipment merit
the final stamp of approval—the insignia which everywhere symbolizes
Quality in its strictest sense—the trademark of John Deere.

JOHN DEERE • MOLINE • ILLINOIS

Could Sam Kier's Refinery Fuel a B-36?

Back in the early 1850's, Sam Kier's five-barrel refinery in Pittsburgh, Pa., distilled crude oil into a fine lighting fuel. But it wouldn't push a piston in today's B-36. For it takes "super high octane" to get a long-range bomber there and back.

Only modern refinery equipment can produce such power-packed fuel in quantity. Unlike Sam Kier's pioneer equipment, today's low-cost, low-maintenance units regularly produce thousands of barrels of high octane fuel daily. They provide the highest percentage of yields-to-charge ever known; continuous operation; adaptability to a wide range of feeds.

In your field too, the *best* equipment is the result of cooperative development between the engineering staffs of progressive Equipment Builders, process engineers and materials suppliers. In developing such equipment, these experienced builders regularly turn to Lukens for its knowledge of materials, as well as its wide range of specialty steel plate, heads and steel plate shapes providing essential design freedom, strength and rigidity.

Even with new equipment hard to get, these builders can often recondition what you have for better, more profitable production. For their names, write us today, explaining your problem. Manager, Marketing Service, 596 Lukens Building, Coatesville, Pa.

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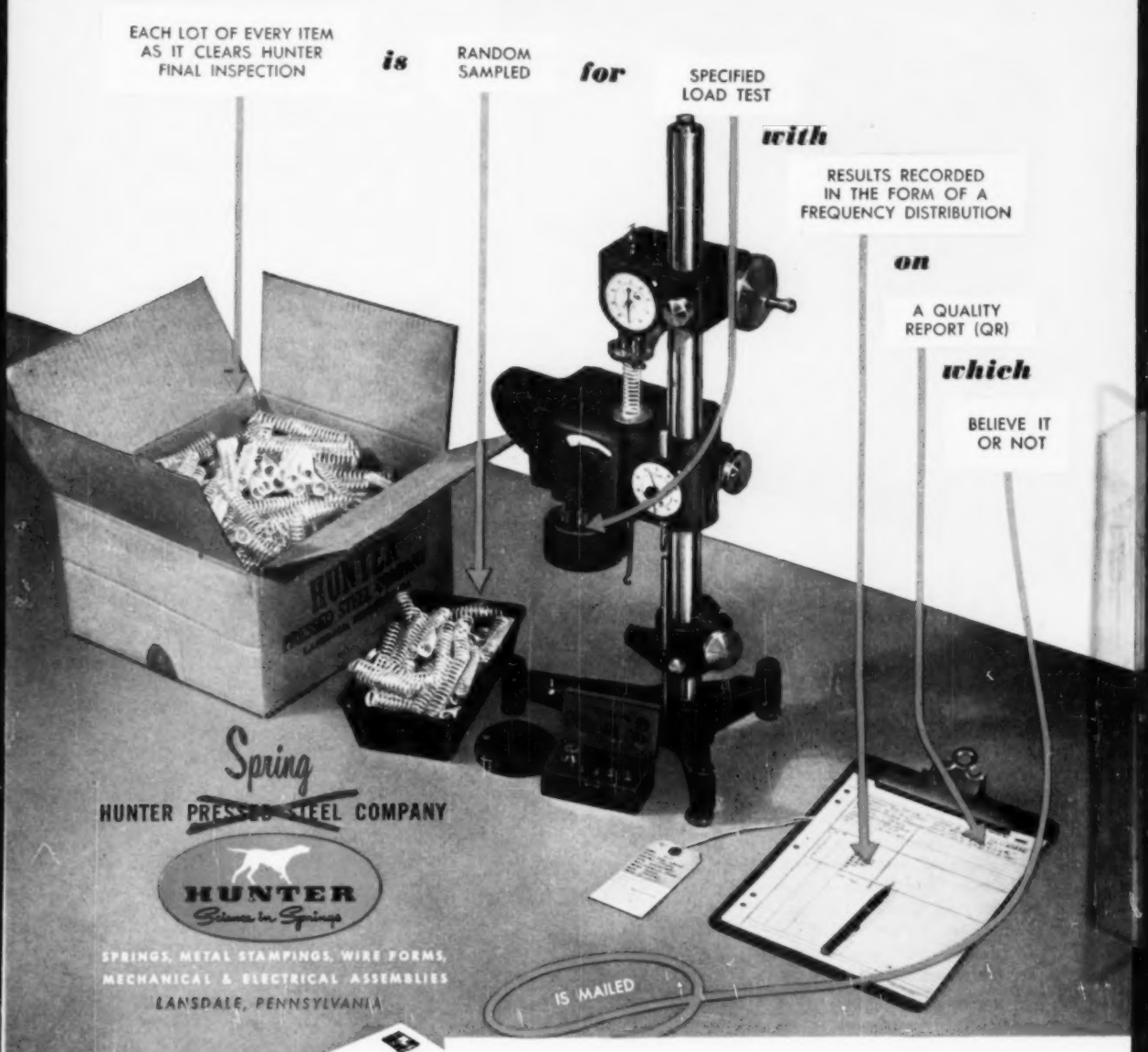
When you specify test loads do you . . . hope for them? . . . grope for them? . . . or make sure of them THIS WAY?



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5 Years Ago . . .

. . . This advertisement appeared in leading trade magazines. With this and other such advertisements, Hunter Spring Company pioneered a new concept in industry —the concept of Quality Reporting, the principal elements of which are detailed above.

For the first time, customers were able to compare quality, consider beneficial tolerance revisions, reduce sampling and know that their order conformed to specifications. This is Quality Assurance.

Our faith in the practical worth of "Quality Control" and "Quality Reports" (Q. R.'s) has long since been vindicated. For today, a rapidly growing list of spring users are demanding that quality be measured this way—and benefiting by it.

How to maintain quality standards in today's expanding production

Johansson

GAGE BLOCKS

In precise measurements — as laboratory standards, or for regular checking of tools and gages — you can insure exacting accuracy and guard against costly rejects by equipping each department with Johansson Gage Blocks. Even with today's need to expand production, you can maintain established quality standards by adding Jo-Block protection whenever you add new men or machines.

Jo-Blocks are made in 3 guaranteed accuracy standards: ±.000002", .000004", and .000008" per inch. Many accessories extend their usefulness. Write for catalog. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.

We urge buying through the Distributor

Brown & Sharpe B·S

AMERICAN SOCIETY OF TOOL ENGINEERS

Industrial Exposition

We congratulate the American Society of Tool Engineers, their officers, their publicity manager, their show manager, and over 400 exhibitors who made the Exposition, held at the Chicago Amphitheater March 17-21, 1952, their most successful show. The very newest in machine tools, tooling, and gaging, was displayed. A feature of the show was Precision Hall, laid out to emphasize "precision control" of manufacturing.

One of the attractions in Precision Hall was the International Harvester booth showing typical successful applications of quality control in many of their plants. This exhibit was prepared under the direction of Harvester's Manufacturing Research Department, at the request of ASTE, as a contribution to industry.

The exhibit, located near the center of the Exposition's "Precision Control Hall," was fifty feet long, consisted of six displays, one each from their Farm Implement, Farm Tractor, Industrial Power, Motor Truck, Refrigeration, and Steel Divisions. Each display, by means of standard quality control charts, pictures, illuminated colored transparencies, cut-a-way models, etc., depicted from one to six successful applications in that division.

A. C. Richmond, General Supervisor of Inspection Methods Research, and well known in ASQC, was in charge of the exhibit. He was assisted by ten quality control engineers loaned by Harvester plants.

Unfortunately this exhibit was almost completely destroyed by fire Tuesday night. However, Thursday morning Harvester had another exhibit consisting of more than thirty quality control charts, pictures of operations, actual machined parts, etc. Many favorable comments were heard both from exhibitors and visitors on the excellence of the "emergency" exhibit.

Mr. Richmond reports that interest displayed in the exhibit at times was such that all of the attendants were busy answering questions about the exhibit and telling visitors where more detailed information could be obtained. He stated that a surprising number of visitors spent from one to one and one-half hours, and some even more in the booth.

Industrial Quality Control

Vol. VIII MAY, 1952 No. 6

Table of Contents

A.S.T.E.—Industrial Exposition 19

Extra Dividends from Quality Control
Levin H. Campbell, Jr. 23

The Significance of Quality Control to Present Day Management
A. V. Feigenbaum 29

Woolen Carding Meets Quality Control
A. G. Klock C. W. Carter 35

Operations Research in Business and Industry
Russell L. Ackoff 41

Engineering for Low Product Cost and High Product Quality at the Western Electric Company
A. C. Jones 53

Building Morale through Quality Control
E. H. Robinson 63

A.S.Q.C. Family Album—1951-1952 72

Convention Program 83

The Interpretation of Chemical Data
W. J. Youden 90

Production Research in the Manufacture of Hearing Aid Tubes
Doris Rosenberg Fred Emerson 94

Practical Aids Ellis R. Ott, Editor
The Error in Measurement
Thomas A. Budne 97

Problems Department
Paul C. Clifford, Editor 102

Book Reviews
A. C. Cohen, Jr., Editor 104

Bibliography
Joseph Moyshin, Editor 107

Forthcoming Courses in Statistical Quality Control 110

From the Scrap Box 110

Management's Corner
J. M. Juran, Editor 112

Index to Quality Control Advertisers 114

Film Review 115

American Society News 116

Classified Advertisements 116

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Extra Dividends from Quality Control*

LEVIN H. CAMPBELL, JR.

Executive Vice President, International Harvester Company

I AM told that attendance at quality control meetings grows larger on each successive occasion. This is indicative of the increasing interest in the subject and the broadening recognition of the utility and versatility of this new tool.

I am especially gratified to see such a large turnout of management men who have an interest in quality control. I would be an enthusiast for quality control programs even if I didn't have access to the reports which show the dividends Harvester gets from its own program. I am enough of a realist to know that the practitioners of the science—the quality control engineers—cannot succeed without solid backing and understanding on the part of management.

My enthusiasm for quality control was aroused before my days in International Harvester—some years back when I was connected with manufacturing in the military establishment.

Statistical quality control was under scrutiny and study in Harvester as long as twelve years ago. Today you can find it in practical operation in every Harvester manufacturing plant. Its progress has been rapid and quality control programs have been steadily enlarged throughout our operations. The practical operation of quality control has been accompanied by research so we may keep constantly abreast of new developments.

TANGIBLE BENEFITS

Harvester feels the program to be of sufficient importance to have its various divisional comptrollers work out a formula for indicating savings in scrap, rework, and inspection. For the first nine months of fiscal 1951 the calculations show a 14 percent improvement compared with the same period the year before.

This improvement represents a comparative saving in the nine-month period in excess of two million dollars which will give you some idea of the potentialities of quality control programs. Although no attempt is made to show exactly how much of this improvement is directly attributable to the quality control program, management believes it is the major contributing factor. The direct expense of the quality control program itself is included in the comparisons.

*Presented before the Executive Luncheon Session of the Sixth Midwest Quality Control Conference. This meeting was sponsored jointly by the Chicago Association of Commerce and Industry, and the Midwest Sections of ASQC, October 3, 1951, at the Hotel Sherman in Chicago, Illinois.

SQC GOES BEYOND THE MACHINE SHOP

Statistical quality control earns its bread and butter and produces the regular dividends in the field of inspection. And, as you know, this kind of quality control is generally associated with machine shops. But quality control is now much more than an inspection procedure or tool. In many places in the Harvester Company it can be found in application outside the walls of the machine shop. I am sure this is also true of other companies which have quality control programs. I would like to talk mostly about the unlikely places in Harvester where you can find quality control programs because it is in those places where the program produces not the regular dividend but the windfall or by-product gain—the extra dividends from quality control.

First, however, let me explain briefly how quality control gets outside of the machine shop and into those unlikely places. Statistical quality control has been so successful in the machine shop that plant people have been calling for the quality control engineer for help when something goes wrong elsewhere in the plant. Indeed, by this time in most Harvester plants, there is what we call a "quality control action committee"—a team composed of the key men in a plant who can get things done if they know what has to be done. A quality control action committee may be composed of the plant mechanical engineer, a division superintendent, the general foreman from the affected department, the metallurgist, and others. A team like this can get at the facts and that is the first step in the solution of any problem.

Let us examine a few cases which are very easy to understand. Bear in mind that people in the plant, excepting the quality control section, from the employee on the job to the plant manager, do not to have to be statisticians to understand the findings of statistical quality control. Indeed, in some of our unlikely applications you will see that some of the statistical formulae are not needed or used to find the solutions to problems.

SQC ON A PAINTING OPERATION

In one of our plants we paint the product by dipping it in a tank. When the painting job was unsatisfactory, and this was frequent enough to make us very unhappy, we were involved in rather costly rework. A quality control analyst was asked to examine the job.

Among other things, statistical quality control charts were kept on the viscosity of the paint which was found to be "out of control." Next, it was found

that this out-of-control condition was caused primarily by insufficient agitation of the paint. When air agitation was introduced into the process, the viscosity came under control.

But the story doesn't end there. Further examination revealed the viscosity to be higher when under control than that required for a good paint job. A lower average viscosity level was established.

Here we went looking for one extra dividend and found three: The quality of the product was materially improved; the rework was almost eliminated; the amount of paint used was reduced approximately 23 percent.

SQC ON A MOLDING JOB

Here is a different kind of extra dividend. A molding job in our Canadian foundry was consistently running 40 percent scrap. After three weeks study, the quality control section established the causes for this high percent loss and corrections were made. The job now runs with about three percent scrap—an improvement of 92 percent.

Since the molder was paid only for good castings, his earnings were materially increased. This resulted in requests from almost all the other molders that quality control charts be placed on their jobs. I ask you to reflect what this can mean in the way of improved employee morale and increased pride in the individual's own performance.

SQC IN SERVICE PARTS

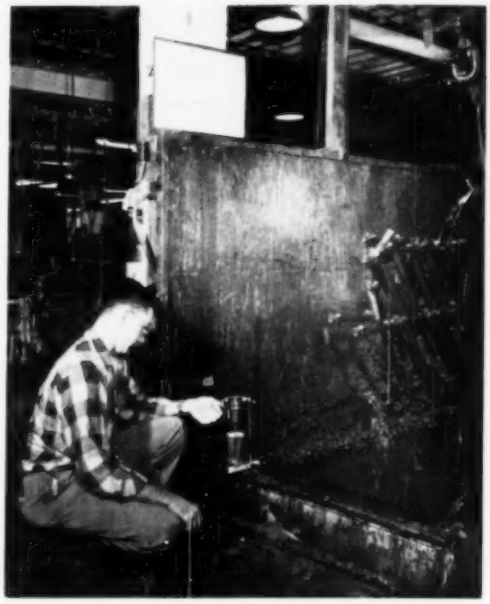
I'd like to take you entirely out of the metal working end of our business now and into a plant service parts department where orders for parts are filled. When order fillers find no stock in the bins, they must make out shortage tickets. The subsequent processing of the tickets to the point where suppliers could be called on for replenishment parts consumed 90 hours total elapsed time. When the quality control section was asked to analyze this procedure, it charted the flow of the tickets throughout the Company operation. When these were displayed to the employees and supervisors involved, many suggestions for improvement were forthcoming. The 90-hour time interval for processing shortage tickets was cut to seven hours.

This offshoot of statistical quality control—called "charting technique" by our people—tends to accomplish the same results without using many of the statistical formulae. This is a case where one picture is worth a thousand words. Charts alone won't improve quality of product or performance but they do point to the place where the corrective action must be taken. In this service parts department, the charts evoked the complete cooperation of the employees themselves who came up with the time-saving suggestions.

In that same department there is opportunity for numerous errors—incorrect counts, improper identification of parts, condition of stock, mixed stock. The volume of orders made the 100 percent inspection check uneconomical. When the quality control section was asked to study this problem, it introduced a sampling plan to get a perspective of the quality of orders shipped. The sampling plan enabled us to calculate the total number of errors made not only by the department but by each individual order filler.

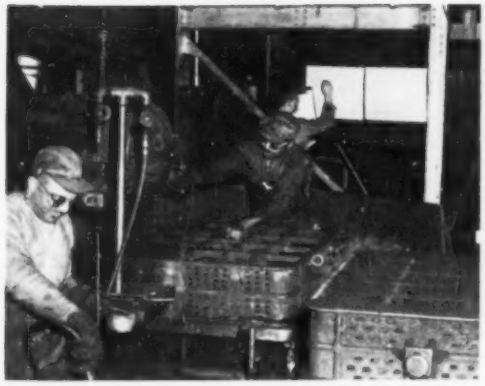
Departmental and individual charts were placed in operation which show each order filler the number and kinds of errors he makes. With his record of performance constantly before him, the employee strives for improvement. Test period checks show a ten percent reduction in number of errors made by order fillers. Consider the extra dividend we get in the way of customer satisfaction when he gets the part he orders!

We had a similar parts-picking problem in a division which packs motor trucks for export. A former practice was to assemble motor trucks destined for export and then tear them down for crating in export boxes—the trucks to be reassembled at destination.

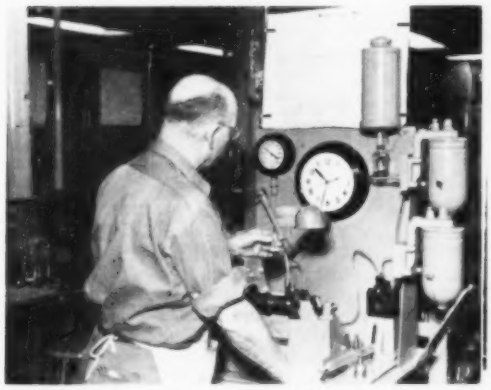


Checking Viscosity of Paint at International Harvester Rock Falls Works. Note SQC Chart above Worker.

Checking Mold Hardness in Foundry at Indianapolis Truck Engine Works of International Harvester Company as Part of Quality Control Program.



Posting Core Hardness on Charts in Sight of Molders.



Checking Metering Unit for Diesel Engine Injection Unit at Milwaukee Works. Tolerance 1 cc Leak Past Plunger in One Minute at 2500 psi Hydraulic Pressure.

That method insured that all the parts of the truck would be in the shipment. This was abandoned in favor of a system under which we omitted assembling the truck and just attempted to pack the right number of parts and components in the export crate. There was an added complication that two trucks were packed in one crate.

Under the new packing system for export, errors averaged 60 for each 100 trucks shipped. You can imagine the customer dissatisfaction which arises at a point as far away as the southern tip of South Africa when he is minus a part for completing the motor truck!

The quality control section investigation and establishment of controls reduced the errors to four per 100 trucks shipped—a reduction of 93 percent in errors.

The Harvester employees as a group who picked and packed the parts were so proud of their performance as reflected by the control charts that they became extremely resentful of fellow employees who were careless and permitted the charts to show "out of control" conditions. Departmental satisfaction was not restored until we had transferred the offending employees and the charts showed the job under control again.

SQC IN FOUNDRY OPERATIONS

I mentioned an extra dividend we found in our Canadian foundry. We also operate 12 foundries in the United States—an industry within an industry. We sometimes tell ourselves that our foundrymen resist changes more strongly than others in the organization. Yet we have installed quality control in our foundries with marked success and with many extra dividends.

On one of our foundry jobs we have two men ramming the drag-half of the mold. The mold hardness of this job is very important. Statistical quality control analysis showed wide variations in the hardness. The investigation also disclosed the cause: the cope molder was doing his job correctly, the drag molder wasn't ramming his side of the mold hard enough. Separate charts for each man showed the individual's ability and skill. The molder with the low hardness was indifferent to the whole procedure. The rest of the men in the department began to notice the difference in the charts. The low hardness man was still indifferent. When he went on his vacation, his replacement brought the hardness up and held it. When our friend returned from his vacation he had no choice but to continue to hold the hardness.

In other places in our foundries—and remember this is not a machine shop operation—we have discovered the cause of and stopped the delivery of sagged cores to the molding unit. In our Indianapolis foundry, for the first ten months of our present fiscal year, we have reduced scrap from 3.61 percent to 2.6 percent—an improvement of 27.8 percent. Statistical quality control has enabled us to work out the relationship between the hardness of the headface and the cylinder bore of one of our new engines, something very important to us. We no longer have to guess at the relationship or, worse still, saw a piece out of each block and take the hardness of the cylinder bore.

I could tell you a number of other foundry dividends but I am going to settle for just one—it has to do with the casting of cylinder blocks and heads. An elaborate venting system is incorporated in water jacket cores to eliminate core gas. Iron sometimes seeps into and blocks the vent, forcing the gas to seek another outlet. Frequently the blocked gas blows a hole in the casting.

On one particular job we knew we had a quantity of vent iron, and scrap was high. Statistical quality control analysis showed 15.8 percent of the castings had vents plugged with iron.

Functional changes in the method of making the jacket core assembly were indicated. When changes were incorporated, the percent of castings plugged with iron dropped from 15.8 to 9.5.

Other changes were made but no further improvement was noted. The control charts, however, did show that one shift was having considerably more vent iron than the other shift. Investigation showed that one core maker had a special set of vent pins. The pins went into his locker when he finished his shift and no one else used them. Measured, they were found to be so long that they left only one thirty-second of an inch between the end of the vent and the casting surface. When the special pins were cut to the correct size, the vent iron dropped to five percent—a total improvement, after many months of patient quality control investigation, of 60 percent.

SQC IN A MACHINE SHOP

I would like to return to the machine shop long enough to tell you of one case which produced improvement not because of inspection of the product but because of a statistical quality control analysis of a machine producing the product. We had trouble for a long time machining gear teeth on this job. Extreme dimensional variations caused considerable scrap on subsequent shaving operations. A batch of blanks which met specifications were fed into the gear cutter. The quality control section took the readings and, in the subsequent plotting of the data, got two normal distribution curves. In shop slang this is called double distribution—something the experts call bi-modal distribution. The experts also knew this could be caused by only two possibilities. The part was held stationary while the head of the machine moved up and down. It had to be either the holding fixture or the head. The fixture proved to be all right. The head had play in it which was equivalent to the spread between the normal distribution patterns found by quality control. The machine tool supplier remedied the head play and the operation has run satisfactorily ever since. In something like five days, statistical quality control had found a sore spot which had troubled the manufacturing works for two years.

SQC AND MACHINE CAPABILITY STUDIES

Statistical quality control has also paid us extra dividends by challenging machine tool performance and by telling us something about engineering tolerances.

We recently retooled our motor truck plants to produce a new line of motor trucks. We bought many new machine tools for this job. Among these were five lathes for machining axle shafts. Ordinarily we set up and run new machine tools in a probationary proving period before accepting them from the manufacturer. In this trial period on the lathes, we applied statistical quality control procedures and discovered they could not hold a specified tolerance of five thousandths of an inch.

We could not accept the machines until they were corrected and the supplier could not improve the machine performance to meet specifications.

Once again our quality control analysts went into action. They found the shafts were being sprung by the method of chucking. We made a new type chuck in our own tool room. With the new chuck, the machine tool held to three thousandths of an inch—well within the limits set by our specifications. The machine tool manufacturer now uses that chuck on all similar machines he sells.

I could take you into this same motor truck plant and show you just the reverse of the case I have just cited. For years we machined a bearing cage flange on a planetary machine with an engineering tolerance of ten thousandths of an inch. Quality control analysis showed that one of our new boring machines was capable of machining that same flange consistently to within one thousandth of an inch. Thus we were able to ask our own engineers to change the specs and make a change in tolerance requirements from ten thousandths of an inch to one thousandth of an inch. Extra dividends in this case were the decrease in the range of spacer sizes, increased facility in correct assembly, and increased ability for more accurate bearing preload.

Section of External Grinding Department at International Harvester Milwaukee Works. Note Large SQC Chart in Full View of Each Operator.

Statistical quality control is being used more and more in our plants in connection with requests for changes in engineering tolerances. In fact, at many of our works, when the manufacturing department requests changes in specifications based on machine tool or process capabilities, it is quite common to send along with the request the charts which show the capabilities of the tool process involved.

SQC AND THE EMPLOYEE

We have an imposing and impressive file of testimonials for statistical quality control from employees. In many cases, after the quality control charts have located trouble spots and corrections have been made, we remove the charts. But time after time we have had requests from employees, even from whole departments, to have their charts returned. They engender competition. They give the man a wanted recognition—a record of his accomplishment up where all can see it. They are reviving that lost pride in individual workmanship.

I read a report recently of one employee who said he first thought quality control was a bright idea to cut his piece rate. Now he says: "You know—quality control is like a new pair of shoes. They bother you a little at first—then you can't go without them."

Last fall in one of our gear and shaft grinding departments, after the completion of quality control investigations and corrective action, we removed the charts because the dimensional scrap had been reduced to the minimum. The department sent a delegation of three of its members to get the charts back. Their special complaint was that their work was better than the night shift but without the charts no one knew that. They also felt that there would be no criticism of their work as long as the charts showed a state of satisfactory control. They got the charts back.

OTHER APPLICATIONS OF SQC

Because statistical quality control is now recognized by us as such a versatile tool, I would be hard pressed

to tell you where it is going to stop in the Harvester Company.

At the present time in one plant alone, in non-manufacturing operations, we have quality controls on 24 different kinds of activities ranging all the way from charts on individual and departmental expeditors to the delivery of blueprints from the engineering department.

In the same plant we are investigating the application of quality control to the typing of invoices, the accuracy of invoices, the processing of export orders on electrical accounting machines, the typing of receiving tickets, the writing of purchase orders, labor turnover, value of commodities by months, inbound and outbound shipments, discount periods and payments on invoices, errors made in shipments, freight charges from suppliers, promises of shipment from suppliers, packaging of service parts, filing, and many, many others.

WHY DOES IT WORK?

The explanation of why it is possible to extend the application of statistical quality control beyond the machine shop and earn extra dividends is a simple one to my way of thinking. Anything that can be measured is subject to statistical analysis. Statistics is no mystery —it is the systematic and logical collection, analysis, and presentation of the data.

Consider what the quality control engineer does. He goes out into the operation at the request of somebody who has a problem. He collects the facts—all the facts. Each fact is a statistic.

Then comes the analysis of the facts. This is done by the quality control engineer with his statistical tools. You don't have to understand these technical tools. You don't have to know what a c or p chart is, or how an average and range chart is made.

Then the engineer presents his data in the form of a picture that any person can understand. That picture is the quality control chart.

What more do you need for the solution of any measurable problem than collecting the facts, analyzing the data, and seeing the picture of the trouble?

I think the time is past when we should keep our aim set on the routine uses of statistical quality control. We should concentrate on seeing how versatile we can make the tool. I can see the day ahead when we are going to reap the largest of all possible extra dividends —improved employee relations—improved human relations—for that is the basic thread that runs through all the cases I have cited.

THE ROLE OF ASQC

Because you are management men, I urge you to see that your people keep up, not only with the routine statistical quality control applications, but also the extensions of the principles into wider and wider fields. Our knowledge of the capabilities of this tool is increasing by leaps and bounds.

It has been historically true of any similar advance in a science that the single individual cannot by himself keep track of everything that is going on. In such periods our technical societies have always acted as the storehouse of knowledge and the clearing house for the exchange of data and information.

Our quality control storehouse and clearing house is the American Society for Quality Control. It is the place where your quality control people can rub elbows with others from whom much can be gained. This is not a society for company memberships. There are no sustaining memberships. It is a society for individuals. My own Company supports from one to as high as 14 or 15 individual memberships in the Society at each of our manufacturing operations in the United States and Canada. I commend the Society to your attention and to the attention of all who are interested in maximizing the gains which may be had from statistical quality control.

As a final word, let me say that as management men you have only one thing to fear from quality control—watch out for the day when someone installs the statistical quality control chart on the performance of the boss!

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The Significance of Quality Control to Present Day Management*

A. V. FEIGENBAUM
General Electric Company

THERE is little question that attention to, and increased understanding of, Quality Control has been one of the most important steps forward that industrial practice has taken in our economy during the past decade. There is equally little question that this attention has provided a quality contribution to defense production of 1951 that the defense production activities of 1941 simply did not enjoy in many plants. There is much that you and I, as Quality Control practitioners, can see as genuine and heartening progress in the last ten years.

A great deal of this progress has shown itself in the development of improved technical methods for use in Quality Control programs. Inspectors, statisticians, engineers, and scientists have reported to their own managements—and often to the world at large—the excellent results experienced from use of these methods in improving quality and in reducing costs. Many of these managements—particularly under the competitive and defense urgencies of recent days—have encouraged these technologists to increase their use of Quality Control techniques. Such encouragement, and its parallel of wider and wider application of Quality Control methodology, represents the current status of Quality Control activities in many plants throughout the country.

With such a generally successful growth pattern, it seems only fair to ask this question: Is it not merely a question of time until the significance of Modern Quality Control for the effective management of industrial operations becomes so well recognized that the activity takes a place in the industrial management kitbag similar to that occupied by such longer established, standard, accepted management tools as Production Control, Wage Rate Administration, Budgetary Control, Personnel Administration? Indeed, some might ask, "Isn't Quality Control already there?"

I do not think so, at the present time. I do not think that we have yet provided the opportunity for any large segment of American industry completely to appreciate the full significance of practical Quality Control to the management of business enterprises.

I submit that a good share of Quality Control success has developed—and, I must hasten to add, necessarily so for a new activity—in relation to individual parts and individual process applications. It has not developed in relation to broad, continuing, factory-wide planning and control programs as are characteristic of effective Personnel Administration, Budgetary Control, and other comparable management tools whose routines and procedures are part and parcel of standard factory practice.

I submit that while our success of the past decade has enabled top management adequately to recognize Quality Control for the first time, this recognition in many instances is that given the pinch hitter who is sent in to save a special situation; it is often not recognition as a member of the regular first team which starts each ball game day by day. I submit that to enable Quality Control to be really effective as a long rather than a short term matter—and thereby enable the activity to realize its genuine significance for modern industrial operations—we must work toward making Quality Control a member of the regular management team during the next few years, just as we worked over the past several years to get it admitted to the management league in the first place.

QUALITY CONTROL AS A MANAGEMENT METHOD

Part of our success in achieving such an objective will unquestionably depend upon the degree to which we can follow the lead of an increasing number of Quality Control Engineers in viewing Quality Control as a business method as well as a series of somewhat independent quality techniques. Our success will depend, in effect, upon the ability with which we can understand the significance of Modern Quality Control as a management method rather than as only a technical tool for product and process analysis.

This view of Quality Control as a management method recognizes that management's quality goal is the same today as it was a generation ago — namely, to manufacture a product into which quality is built and maintained at the most economical costs yielding full customer satisfaction. It equally recognizes, however, that present-day interest in Quality Control by management people may largely be traced to two factors which have developed in the past 10 to 15 years to make difficult the achievement of the management quality goal. These factors are:

First: A Change in Technology. Customer's quality requirements have become far more precise than ever before. The regulator that was acceptable in 1941 must perform with much greater accuracy today if it is to serve certain portions of the modern market. The machined part that could once be checked with a pocket scale must now be carefully measured with a pair of micrometers or even an air gage. The copper bar that could once be accepted if it were "reddish brown" and "shiny" must now be subjected to elaborate tests for

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physical characteristics and for electrical conductivity.

Second: A Change in Human and Organizational Relationships. Plant expansion and labor turnover have wrought many changes in once stable work groups. Green operators are again the rule of the day in many shops engaged in defense work.

Several of the product quality responsibilities, which were once the exclusive province of the shop foreman, are now widely distributed among many factory specialists. Poor quality of a part may be due to unsatisfactory specifications written by the Design Engineer, to faulty procurement by the Purchasing Agent, to inadequate testing by the Laboratory Technicians, to unsuitable processing equipment installed by Methods Engineering. In the modern specialized factory, Quality Control simply can no longer be pinned down exclusively to the team of the factory foreman and the old 100% "sort the bad from the good" inspection department.

The view toward Quality Control as a mangement method recognizes that a major contribution has been made in a relatively few years by Quality Control practitioners in respect to the first of these two factors—the technological. This contribution has been very largely in the form of the development of industrial statistics to the point where it is now recognized by most progressive managements as an indispensable Quality Control tool. For these managements, a statistical point of view may now be discerned in their thinking about product quality: namely, that variation is inevitable among their manufactured products, and that this variation may best be studied and controlled by the selection and analysis of small samples.

But the view toward Quality Control as a management method also squarely recognizes that the changes in technology, that have affected product quality, have required the use of many progressive technical methods other than statistics—tool and die control, preventive maintenance, inspection planning as a few examples. This view recognizes that many plants have far to go in recognition and use of these technical methods other than statistics and that they have particularly far to go in their integration of such methods with the plant Quality Control program.

This management view of Quality Control also realistically recognizes that many Quality Control programs have not yet even begun to face up to the second of the two factors which in recent years have come to complicate achievement of management's quality goal—namely, changes in human and organizational relationships. It recognizes that the development of factory-wide Quality Control policies, organization practices, and standard routines have frequently been subordinated almost completely to purely technical considerations.

CONTENT OF A FULLY SIGNIFICANT QUALITY CONTROL PROGRAM

So this management view sees a truly significant plant Quality Control program not as almost entirely a matter of industrial statistics, nor as almost entirely a matter of reject troubleshooting—but rather as an overall, factory-wide program for attaining management's quality goal. This program utilizes these individual quality techniques if and as they may be required by the plant's administrative structure for Quality Control.

Modern Quality Control, therefore, may be defined as follows, from this administrative point of view.

"*Quality Control is a plant's system for programming and coordinating the quality maintenance and quality improvement efforts of the various groups in the plant so as to enable production at the most economical levels which allow for full customer satisfaction.*"

A more popular, slogan-like version of this definition is that "Quality Control means programming the job of making the product right the first time at the best costs which enable full customer satisfaction."

From this administrative point of view, a Modern Quality Control program to be fully effective must enter into all major phases of the industrial production process. It starts with the customer's specification and the sale to him, goes on to engineering, laboratory work, and materials purchasing through factory methods, job planning, manufacturing, and mechanical inspection and electrical test, to packaging and shipping and then back to the customer whose needs must be satisfied with a quality product. The activities to support this so-called Modern Quality Control cycle fall into four natural classifications which may be expressed as:

1. The control of new designs and new products, or "New-Design Control."
2. The control of incoming purchased parts and materials, or "Incoming Material Control."
3. The control of parts and batches from machines, processes, and assembly lines, or "Product Control."
4. The conducting of special tests of factory and processing problems, or "Special Process Studies."

The full long-range significance of Modern Quality Control to top management is a composite of the management significance of each of these four Quality Control activities. It may be in order, therefore, to discuss in some detail these activities, or "Jobs," with emphasis upon the management problems to which they address themselves and the solutions to these problems which have been built into the activity.

FIRST: NEW-DESIGN CONTROL

Every factory has the example of a product the quality standards of which have been continually troublesome to maintain. The quality problems resulting from manufacture of this product are often never solved because, in the language of plant personnel, "It would be too expensive to do so."

Similarly universal is the conflict between shopmen and design engineers on those parts tolerances which the shopmen insist are far narrower than the use of the part requires. On these parts engineers may privately admit that "We call for ± .022" only because it increases the likelihood of our getting ± .005"."

When a situation of this sort exists, it inevitably results in lack of respect for tolerances established on drawings and on specification sheets. It is also accompanied by excessive expense in securing and using manufacturing facilities of unnecessarily high precision.

Again, there is the perennial case of the engineer who has carefully designed his product, rigorously tested two or three toolmakers' models which perform satisfactorily, then complains bitterly about the "factory's incompetence" when large percentages of the product fail to perform properly when produced in

mass quantities. Yet, this poor performance may have been inevitable owing to overly great tolerance buildups or to a statistically unsound testing program.

These situations are some of the more readily apparent illustrations of management's need for a properly coordinated, regularly scheduled program directed toward analyzing newly designed products for possible quality troubles before active production is started. This type of program tends also to improve several less obvious situations that may have long existed in the factory without even being recognized as problems affecting the quality of new designs.

There may be, for example, no organized means for pumping back to the design engineer, information from the plant laboratory about new materials or processes. Mechanical inspection or electrical testing groups may be forced to wait for information on what they should inspect on test until production has actively started and many defective units have been scrapped. Parts tolerances may be selected with no knowledge of or reference to the accuracies that may be actually held on the plant's machine tools and processes.

Sales efforts in product planning and merchandising may work in directions opposed to the design actually being developed. Desirable cost standards for parts inspection and bogeys for manufacturing losses may be established only after the design has been in active production for a considerable length of time.

Data on field tests and performance of units in the customers' plants may not be effectively reported by the field organization for use by the engineer in the design of products similar to the one under development. Guarantees may be established based upon the performance of a few specially made models rather than upon a sufficient quantity of actual production units. Company efforts toward standardization and product simplification may be thwarted by the fact that the new design calls for many new and special parts. Manufacturing employees may be considerably handicapped by the nonexistence of adequate quality specifications.

These problems are too often faced and solved long after the product design has been frozen and a considerable investment has been made in inventory and in processing equipment. The latitude of decisions affecting process improvements or inspection schedules after the actual design has been completed is obviously much more limited than it is during the development stage of the product.

That problems of this sort should be faced and solved has been recognized as a "good idea" for some time. Action on the good idea has frequently been lacking, however, because no machinery has been developed to carry out the required program. The Quality Control activity called New-Design Control provides management with this machinery in a complete Modern Quality Control program.

The new-design tool is a planned method for balancing the quality costs of a new product design with the service that the new product must render if it is fully to satisfy the customer. For the word "quality" in Quality Control does not of course have the popular meaning of "best" in any absolute sense. It means "best for certain customer conditions". These conditions are the actual end use and the selling price of the product. Product quality as a general rule, therefore, is not thought of by modern management apart from product cost. New Design Control, as a regular part of normal factory routine, aims to minimize these costs and to maximize customer satisfaction.

New-Design Control activity includes all the Quality Control effort on a new product while its marketable characteristics are being decided, while it is being designed, sold to the customer, planned for manufacture, initially costed; and while its quality standards are being specified and inspection and test routines are being established to maintain these standards. In the case of quantity production, New-Design Control activities typically are completed when pilot runs have given proof of satisfactory production performance. With job-shop production, the routine ends as work is being started on the manufacture of component parts.

New-Design Control, therefore, is significant for management in that it helps to plan the quality of products, in place of the unplanned, uncoordinated, reject-ridden new product lines which have plagued top management so often in the past decade.

SECOND: INCOMING MATERIAL CONTROL

Visualize the following situation A battery of turret lathes has started to machine a lot of casting bodies Tools start to break; castings fail to "clean up". The machine shop foreman reports to his superintendent that the entire lot is defective because of "hard spots". Since these are the only casting bodies available in the factory, the assembly line on which they are to be used must shut down until new castings can be secured from the foundry. Production stops; employees on the assembly line are sent home with all the attendant industrial relations problems incident to such a step.

Visualize an additional situation involving castings: Precision machining is performed at high cost on a pump casting. At the twelfth machining operation, blowholes and porosity show up. These defects cause the scrapping of the casting and the loss of the effort spent on the previous 11 operations.

In both these instances, ineffective control over incoming castings was the direct cause of the manufacturing difficulties. But these are failures detected before shipment; many similar situations could be cited involving quality troubles in the field caused by inadequate control of incoming materials. This is one example: Bearings on a certain motor type began to fail prematurely after only one year of operation in the plant of the customer which purchased the motors. The failures were finally traced to low-quality materials that were originally manufactured into the bearing linings.

Since no adequate functional preshipment test had been performed on the motors, it was only upon the control of incoming bearing lining materials that quality depended. An unsatisfactory incoming control routine resulted in the considerable customer dissatisfaction developing from these bearing failures.

Control over incoming material may also suffer because of inadequacy or inaccuracy of inspection measuring equipment. Incoming inspectors may lack in proper training or in sufficient understanding of inspection objectives. They may not be provided with satisfactory specifications for judging conformance of materials.

Incoming material may be damaged by poor handling during its receipt and travel through the plant.

Certain materials which are placed on the shelf after incoming acceptance—insulating strips, bellows which require "aging"—may be harmed owing to improper storage facilities. Ineffective means for tagging and disposing materials found defective may result in occasional lots of the material finding their way into active production.

These instances illustrate the first of the two aspects in which the old-fashioned incoming-material procedures of many factories have been unsatisfactory in assisting management to achieve its product quality goal: namely, these incoming-material procedures have too often permitted defective materials to be accepted by the plant for use on its production line.

The second aspect in which these incoming-control procedures have led to problems is more directly related to economics. In some plants incoming-material routines have been unnecessarily cumbersome and drawn out. Too much time and money have been spent to achieve the amount of control that is required for the materials and parts received.

A case of this sort may be briefly described: One manufacturer discovered that his inspection force had been 100% inspecting all incoming brass rod for its outer diameter dimensions. The inspection force kept several charts and incoming-material inspection records on this brass rod. These charts showed the quality performance of the vendor in considerable detail.

The inspection force was quite proud of its extensive control routine for this material. Yet, for 14 months there had not been a single reject of brass rod at incoming-material inspection. Obviously, the 100% inspection as well as the very considerable charting and recording routine was unnecessarily expensive.

Situations could also be cited illustrating uneconomical material purchase prices that result from an inadequate program of material control. In too many instances, materials—steels, forgings, detail parts, springs—have been bought at prices which reflect excessive costs for unnecessary quality extras or for special tests and inspections. These special requirements may have been required for applications of these materials at one time; they may, however, have been retained in purchase specifications long after the need for them has passed.

Plant relations with respected vendors may be strained in several ways. One vendor may complain bitterly about the rejection of thousands of his parts because of defective finish; he may insist that, according to the standards of his own plant, he has met the purchase specification which states only that "fine finish is required". Another vendor may embarrass a multidivision plant by pointing out that there is a completely non-uniform interpretation of specifications on the same material among the divisions of the plant.

An even more serious incoming control problem for management is that which has all too often been faced by plants which sub-contract parts and sub-assemblies. Particularly under the expansion of defense orders, some of these plants are sometimes quite suddenly forced into the realization that the uncoordinated, unplanned inspection requirements of the individual subcontracts that have been let, seem to indicate that the company must somehow provide floor space and equipment for a number of receiving inspectors which exceeds by several times the total of the direct labor employees in the company.

Successfully to come directly to grips with incoming material problems of this sort is the purpose of the Incoming-Material Control activity of a Modern Quality Control program.

This Incoming-Material Control activity involves, therefore, the receiving and stocking, at the most economical levels of quality, of only those parts whose quality conforms to specification requirements. The scope of Incoming-Material Control's factory routines covers all of the Quality Control effort carried on while material purchase contracts and prices are being arranged, and while these materials are being received, inspected, and stocked by the purchase plant. Incoming-Material Control involves techniques in purchasing, inspection, and laboratory as well as in other functional fields. It concerns relations with vendors on quality matters. It applies to all parts and materials received by a factory for use in production; in some shops it also includes control over materials used in such plant service activities as maintenance and plant protection.

Material-control routines of a decade ago concentrated most heavily upon receiving inspection procedures. Large areas lined with inspection equipment and peopled with an extensive inspection force were taken to be representative of sound programs.

Modern Incoming-Material Control technique is not so directed. It recognizes that widespread incoming inspection does not, of itself, relate very closely to achievement of management's quality goal. Modern Incoming-Material Control places its strongest emphasis upon control of material at its source—in effect, upon close product-quality relationships between the vendor and the purchaser. Receiving inspection is used as an adjunct to this relationship rather than as the whole of Incoming-Material Control.

The significance of Incoming-Material Control to management in essence, therefore, is that the activity assures management that the parts and sub-assemblies stocked by a plant are of satisfactory quality so that worries about unbalanced inventory may be minimized, so that these parts have been accepted from the vendor through a close working relationship that enables minimum outlay for receiving inspection or test, and so that the prices paid to vendors for the parts reflect the realistic present day use of these parts and involve no unnecessary charges for quality extras.

THIRD: PRODUCT CONTROL

The ratio of manufacturing losses to total planned direct labor cost reflects, for many plants, startling evidence of the effect of inadequate control of product quality during manufacture. These manufacturing losses—composed of such elements as costs for scrapping or reworking material of unsatisfactory quality—represent a ratio of as high as 20 to 50 percent in some plants.

High costs for the inspection of manufactured parts and materials may be another evidence of inadequate control. These high costs for inspection were once justified in some quarters as a reflection of good control of product quality. Modern industrial thinking now recognizes that these costs may, on the contrary, result because control has been *poor*. Satisfactory quality may not have been built into the products before they were presented for inspection. This modern thinking recognizes that high inspection costs

may merely be a different side of the high manufacturing-losses coin, with both types of expenditure directly traceable to unsatisfactory control over plant quality.

Yet high inspection costs and high manufacturing losses may at least indicate that some portion of control has been exercised over quality, namely that unsatisfactory parts and materials are being "caught" before they are shipped to customers. Even more distressing for many plants are the problems which develop when this unsatisfactory material is actually shipped to customers. Arising from these situations are the numerous customer complaints, the high outlays for which result either from the need for completely replacing the complainant's material or from the need for repairing or servicing it.

The immediate financial loss due to complaints is only part of this particular problem. While less tangible to a factory in the short run, the loss of customer good will from these complaints will ultimately have a direct bearing upon the marketing position of the plant. All of us dread remarks from our customers that "You can't depend upon that company's products." Such statements may presage a serious decline in the company's commercial position.

Another aspect of the complaint situation relates to those products upon whose proper performance human comfort and safety depend. Poor quality of these products may raise much more serious and immediate issues than long-term decline in the company's commercial position. One poor quality lot received by customers may be all that is required to put a firm out of business.

Poor control over quality during active production may cause management financial problems of a more subtle form than that of losses or complaint expense. It may be reflected in the increases in planned cost on a part to allow for second operations like finish tapping or grinding "just to be safe". It may be reflected in machine overruns or in the informal procedure of order clerks to "order a few percent more just to allow for possible rejections."

These cost situations tend broadly to indicate the needs of a plant for adequate control of products. Other somewhat more specific factors may also be cited:

There may be, for example, inadequate maintenance of the condition of processing equipment and tools, or lack of knowledge of the capabilities of these processing equipments. There may be ineffective utilization of engineering specifications.

There may be lack of quality-mindedness among shop employees. This failure in attitude may revolve in a vicious circle with such conditions as poor housekeeping and loose inspection performance. There may be failure to keep operators informed of plant quality objectives or to go over with them defective work they have produced. In plants which have extensive report systems covering such elements as car loadings and labor take-home records, there may not be even the crudest attempt at informing management of the quality index of the manufacturing operations of the plant.

Solution for management of problems of this sort depends upon the Product Control component of a plant Quality Control program. This Product Control activity involves the control of processed parts, batches, and assemblies at the source of production so that departures from the quality specification can be corrected before defective parts are produced.

Product Control includes all quality-control activity on a product from the time it is approved for production and its materials are received to the time it is packaged, shipped, and received by a customer who remains satisfied with it. If the product is produced in mass-quantities, Product Control activities center on the parts themselves; if the product is manufactured in job lots, Product Control activities will center on the processes by which it is produced.

Key man in the Quality Control organization for Product Control is the factory foreman. All procedures are built around him and his employees, since it is of and through them that the bulk of Product Control activities must be carried on.

The Product Control activity provides

1. A channel of communication for product quality information among all concerned employees and groups, and
2. A means of participation in the overall plant Quality Control program by these employees and groups.

The significance of Product Control activity for management is, consequently, many-sided. It assures management both of the quality of its manufactured items, and of the maintenance of the costs associated with building and maintaining this quality. Perhaps of even greater significance to management is the positive effect of Product Control in building up foreman and operator responsibility for and interest in product quality, thereby minimizing some of the most troublesome frictions that affect plant industrial relations programs.

FOURTH: SPECIAL PROCESS STUDIES

If time were to permit, we could make an analysis of this fourth Quality Control activity just as we have analyzed the other three, with emphasis upon the management problems in the area and upon Modern Quality Control's approach to these problems. I think that we would find from such an analysis that management's major problem here has been that of the uncoordinated, disjointed, sometimes frenzied and frantic, often ineffective efforts which descend upon some plants minutes after existence of a quality epidemic in the field—or in the shop itself—has been telephoned in. Special Process Studies approach this problem—and thereby provide deep significance to management—through

1. Coordination of plant effort so as to utilize all factory resources in an integrated approach to the problem, and through
2. Employment of the best technical methods—particularly the design of experiments and related techniques—so as to enable both a sound technological attack on the problem and to encourage a solution whose reliability or lack of it is quite definitely understood.

LONG-TERM SIGNIFICANCE OF QUALITY CONTROL

From this review of the four Quality Control Jobs, it is quite obvious that management's quality problems are not a matter of receiving inspection alone, nor of reject analysis alone, nor of process analysis alone. Instead, they are problems which are deeply entwined with the very roots of the business enterprise—with commercial activities, with inventory control, with product planning, even with industrial relations. The contributions of Quality Control nationally to solution of some

of these problems has, of course, been highly significant through the development of and utilization of individual Quality Control techniques.

But the deeper, long-term significance of Quality Control is not from individual, intermittent applications of these methods. It is rather from an overall, factory-wide program through which Quality Control can come to grips on a day-by-day basis with all the quality problems that plague management rather than with only a few of them. It is this kind of Quality Control that I think Quality Control Engineers have in mind when they refer to the activity as a management method. It is this kind of Quality Control program wherein the component functions are all of the four Quality Control Jobs that we have been discussing rather than only one or two of them. It is this kind of Quality Control program which provides management with the widest benefits from Quality Control techniques in the:

improvement of product quality;
reduction of manufacturing losses and costs;
improvement of product designs;
utilization of scarce resources, like materials and machines, more efficiently and more flexibly (which incidentally some economists feel is one of the major potential contributions of Quality Control work to our industrial economy);
elimination of production bottlenecks;
improvement of processing methods;
encouragement of a better spirit of quality mindedness throughout a plant.

SUMMARY

In summary, Quality Control has its greatest significance as a management method—as essentially a broad, factory-wide, administrative cycle of control of new designs, incoming materials, parts, batches and assemblies. The individual technical quality methods—important as they are—are employed in this administrative process as parts of the overall program rather than as Quality Control programs in themselves.

There are, of course, a number of plants throughout the country which are effectively employing this broad, factory-wide concept of Quality Control. Yet it is apparent to all of us that a very large proportion of Quality Control activities have not yet matured to this point.

The challenge before us as Quality Control proponents is, therefore, to assist industrial Quality Control activities to grow and mature into a management method on this broad basis. With such maturity—and only with it—can we expect Quality Control to be fully accepted by industrial top management as it has come to accept over the years other management methods like Production Control and Personnel Administration.

I am confident that as this challenge is met we shall, in the months and years ahead, come to see Modern Quality Control significantly become one of the principal tools available to industrial top management in pursuit of its most important objective: to manufacture products into which quality is built and maintained at the most economical costs which yield full customer satisfaction.

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Woolen Carding Meets Quality Control

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THE scientific principles of Quality Control, applied to an age-old process, have resulted in an improvement in product quality of nearly 100 percent. Specifically, the study of woolen carding, conducted by the Engineers of the Bigelow-Sanford Carpet Company, has led to the discovery of a new principle in carding and the design of an inexpensive attachment for this machine which makes possible the manufacture of textile yarns with uniformity previously unattainable. This device is readily adaptable to woolen cards and is being made available under license by Bigelow to both the Davis & Furber Machine Company, North Andover, Massachusetts, and the Whitin Machine Works, Whitinsville, Massachusetts.

The process of carding is one of the oldest—and most fascinating—known to man. The basic operation in textile manufacture, it forms the essential link between raw lumps of tangled fibers and the smooth finished yarn from which a fabric is woven.

There are two systems of carding wool—the Worsted and the Woolen system. The difference in the cards for the two systems is the form in which the product emerges.

From a worsted card, the fibers are condensed into a single strand known as "sliver." In contrast, the woolen card is equipped with a means whereby the carded web is divided into a number of individual strands called "ends" of roving.

In the carpet industry the majority of yarn is produced on the woolen system. It is this system upon which we will focus our attention.

Shown in Figure 1 is a typical three cylinder tape-condenser woolen card. The feed box, to the extreme right, receives amounts of scoured—and sometimes dyed—wool, in much the same form as it is taken from the sheep. The function of the feed box, then, is to meter this wool, by means of a weigh pan, onto a moving apron. From this it is introduced into a series of cylinders covered with coarse steel teeth which break apart the matted clumps and prepare the fibers for the principal action of carding.

This action commences in the first of three (or two) main cylinders. It consists of combing the fibers between fine wire teeth mounted on counter-revolving cylinders, parallelizing them to some extent and intermeshing them into a thin, gossamer-like web. This web is condensed into "drawing" and carried by an intermediate feed to the next main cylinder. Here the fibers are again combed and emerge as a web.

Finally, this web is divided into the individual ends of roving by either leather tapes or cylindrical rings, passed between rub aprons to impart a certain degree of cohesiveness, and wound onto large spools in preparation for the next operation.

In considering the quality aspects of any process, one looks primarily for uniformity. The quality characteristic of greatest importance in the carding process is the density, or weight per unit length. Since the weight characteristic of the yarn is determined by the card and since excessive variation in weight can result in fabrics of unsatisfactory quality, it is imperative that this variation be kept to an absolute minimum.

By "absolute minimum" is meant variation due only to pure chance. For well over one hundred years, it has been recognized and accepted that the weight of woolen yarns varies widely. However, the extent to which chance causes affect variation has never been accurately determined. This means that considerable study must be devoted to answering the question, "How much variation is inherent in the process and how much variation is due to causes which can be corrected and controlled?"

Such a study was conducted on the carding process at the Thompsonville Plant of the Bigelow-Sanford Carpet Company during the summer of 1948.

In conducting a study of this sort, perhaps the best approach is to define how the process is currently running. This is accomplished simply by allowing the machine to run without adjustment, and measuring enough samples of its product so that an analysis may be made.

The accepted means of taking

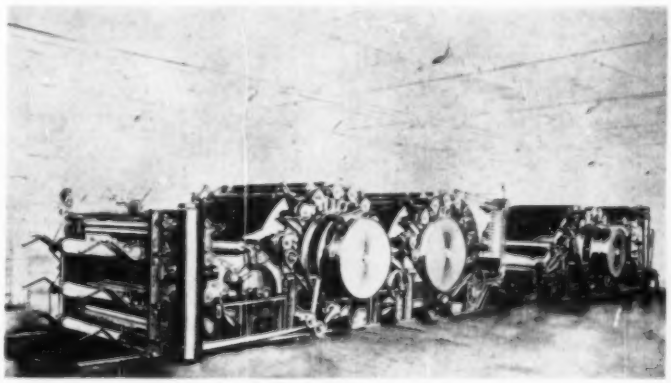


Figure 1—**Whitin 3-Cylinder Woolen Card**

measurements of roving in the textile industry is to weigh a given length of all ends on a jack spool and consider this as the "unit of product." This was done for an entire spool from a card selected by the production supervision as being one of the best quality performers. Some 450 consecutive weighings were made, of which a typical section is shown in Figure 2.

It will be noticed that many tests fall outside of the specification tolerance. Further, these tests seem to fall in a cyclical pattern, and it was found that this pattern repeated itself somewhat irregularly throughout the spool. Translating the length of the cycle into units of time, it was found that the high points came every ten or twelve minutes, and this was the clue to the cause for this excessive variation. The only operation of the carding process which occurred with this frequency was the manual loading of wool into the feed box. It was easy to visualize that the effect of packing the feed box too full would mean roving very much heavier than standard, considering that the converse is true, i.e., a nearly empty feed box will result in very light roving.

If this were true, the same effect could be obtained by purposely packing a feed box and allowing it to run until nearly empty. The graphic result of just such a procedure is shown in Figure 3.

This chart shows averages of ten consecutive weighings instead of individuals, as shown in Figure 2, and is plotted on a time basis. It will be noticed that within three minutes of filling the feed box the weights were in excess of the upper specification tolerance and that these weights amounted to as much as 21%, above the standard. These heavy weights continued for approximately twelve minutes, during which time nearly 600 yards of roving were produced. It should be noted in relation to the rapid dip and rise of the weights at about fifteen minutes that this was due to a drive belt having slipped off the feed box and consequently the weighpan had missed one drop. For the next twenty minutes or so, the weights were within specifications. After forty minutes, however, the feed box would become sufficiently low to produce sub-standard roving. Of course, the extent to which this could drop is only a function of how empty the feed box is allowed to run. After about forty-seven minutes, the

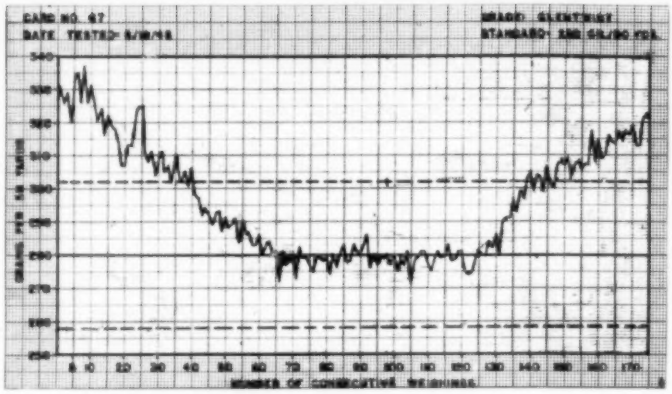


Figure 2—**Longitudinal Variation of Card "as Running"**

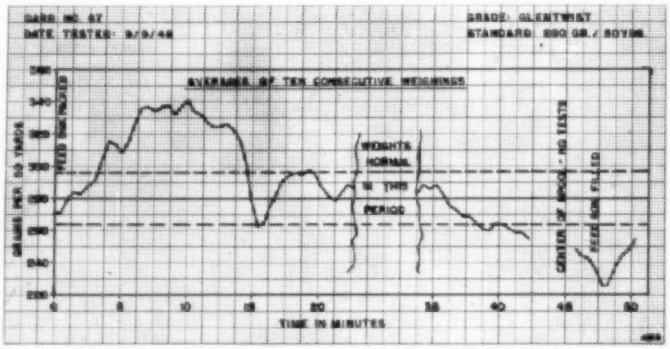


Figure 3—**Effect of Improperly Tended Feed Box**

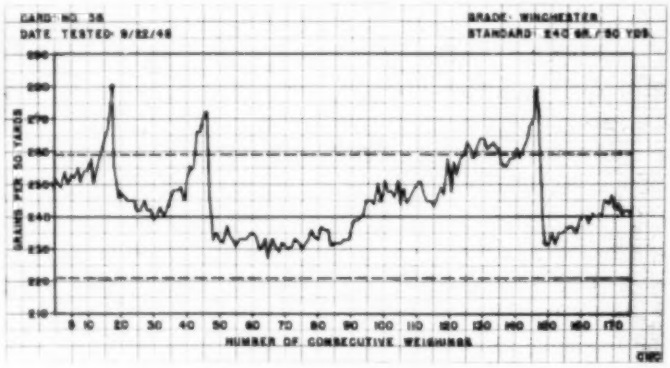


Figure 4—**Effect of Uneven Motion in Feed Apron**

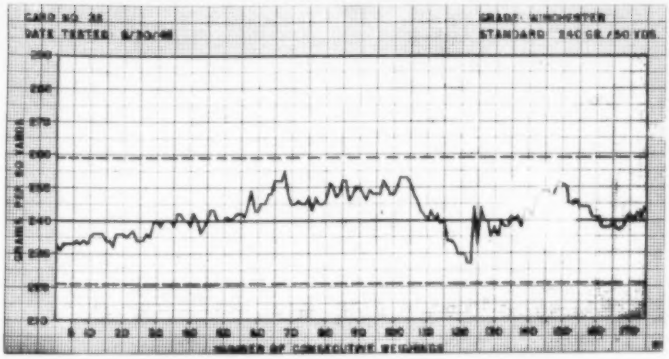


Figure 5—**Controlled Longitudinal Variation**

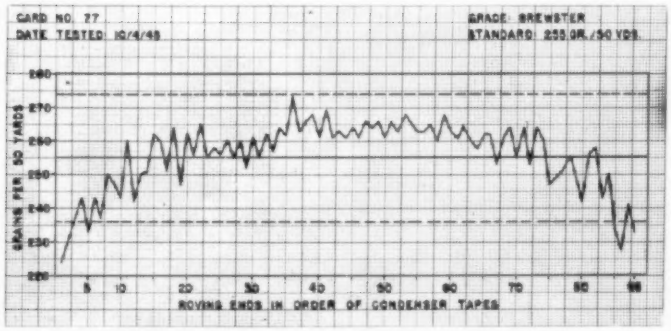


Figure 6—**End-to-End Variation of Card "as Running"**

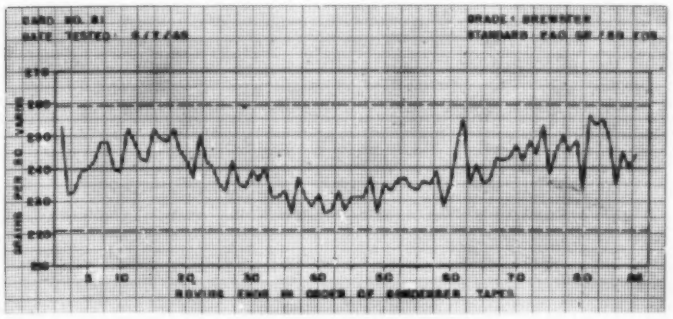


Figure 7—**Effect of Tightening Tapes**

feed box was again filled, and the weights started to recover.

Since it is desirable to produce roving within specifications and since this analysis showed that a great deal of variation stemmed from improper feeding, a scheduled controlled feeding wherein the box feeder deposits a known weight of wool every ten minutes was adopted. If this scheduled feeding had eliminated all excessive variation, such a test on another card should show all values to be well in control. Figure 4 shows the results of just such a test.

The peculiarity of this test is that irregular "peaks" were appearing. This manifested a sudden increase in the weight of the roving of as much as fifty grains within seven or eight yards. The result of this would undoubtedly be heavy ends in the finished carpet. The irregularity of these peaks indicated to the carding foreman that this might be caused by the uneven motion in the feed apron, and Figure 5 shows results of a test run on the same card after the motion of the feeding had been made smooth.

Whereas it might be open to question whether Figure 5 reports purely random variation, it, nevertheless, indicates that the product is well within specified limits, which are based upon product requirements.

Figure 5 is entitled "Controlled Longitudinal Variation" because these weighings are measures of the variation along the length of the card. However, this tells us nothing of the variation across the card, i.e., among individual ends, because this system of weighing all ends has the effect of averaging out differences in weight.

Since there existed no standard method of testing the individual ends, it was necessary to devise a special technique. This was developed so that an accurate gage of the eighty-eight ends (four spools of twenty-two ends each) could be obtained. Figure 6 shows this end-to-end variation of the card "as running."

The chart also reveals nine out of eighty-eight ends as being outside of the specifications. The appearance indicated excessive variation, and when shown to the foreman, this was interpreted as the result of loose tapes in the front section of the card. However, there seemed to be a general trend across the card of increasing weight toward the center. A subsequent test, reported in Figure 7, after the tapes had been tightened, brought this characteristic curve into much sharper focus. The tape-to-tape variation has been noticeably decreased, but there still are five ends out of the specification tolerances. Many subsequent tests of this sort were run, and this characteristic curve repeated itself consistently despite the fact that all possible adjustments were made on the card.

This then indicated the presence of a heretofore unrecognized cause of excessive variation, and a thorough engineering study was made to determine this cause.

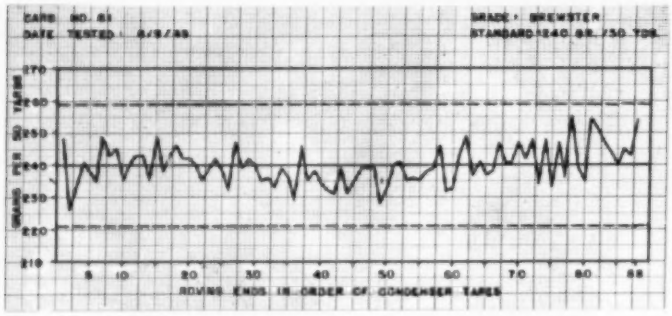


Figure 8—**With Traveller Speed Control Device—½" Eccentric**

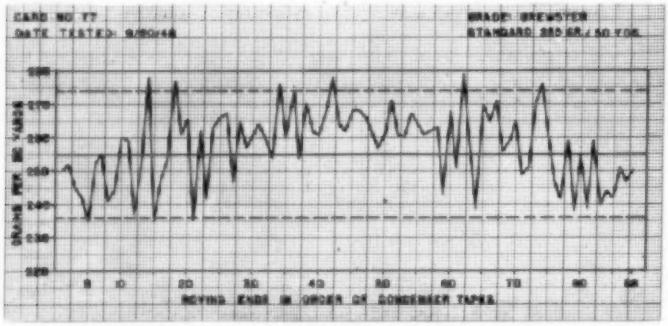


Figure 9—**With Traveller Speed Control Device—1" Eccentric**

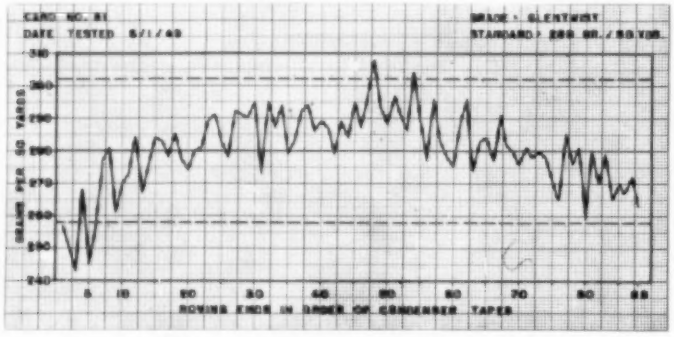


Figure 10—**With Traveller Speed Control Device—0" Eccentric**

The results of this study indicated that the operation of the intermediate feed was causing a certain stretching of the drawing as it was deposited at the sides of the feed table. Therefore, it seemed logical to overcome this by driving the traveller at a slower speed as it approached the sides and an accelerated speed as it moved past the middle. This would deposit more wool on the sides and less in the middle. The variable speed mechanism for carding apparatus* (otherwise known as the "Traveller Speed Control Device") has been developed to serve this function. This device works on an eccentric gear principle, and is controllable through a wide range, giving it flexibility to handle all machine conditions and type of stock. Figure 8 shows the result of setting the device at one-half inch eccentric, and it will be seen that the characteristic curve shown in Figure 7 has been effectively straightened. None of the ends are outside of the specification tolerances and the characteristic is relatively flat.

As substantiation that this device has the desired effect upon the weights across the card, Figure 9 shows the characteristic with the eccentric set at one inch. There is a noticeable downward bow in the middle. Finally, Figure 10 shows the result of setting the eccentric at 0", or in the concentric position, at which adjustment the characteristic duplicates that of the card before the installation of this control.

The use of this device has resulted in a reduction in roving variation of approximately 50%. It would be unnecessary to describe in detail the advantages of this increased uniformity both from a product and a cost point of view.

Here then is an industry, many years old, in which the techniques of Quality Control have been employed to advance existing knowledge. Considerable improvement has been achieved in the basic operation of carding, a process, in which, for many years, improvement was thought improbable. New facts presented in a concise manner were used to disprove some theories and to prove others. Shop personnel, steeped in many years of experience, were thoroughly convinced upon presentation of these data. In providing a new tool whereby quality can be controlled, the critical emphasis has been shifted from the operator to the machine and has led to a more basic understanding of the principles involved. The favorable impact of this technique upon quality has been dramatic. Finally, the consumer benefits by an improved, superior product.

In conducting this study, the inspirational guidance of Dr. J. M. Juran, Consulting Management Engineer, together with the able cooperation of both production and staff departments, has been of inestimable value, and is hereby gratefully acknowledged.

*U.S., Canadian, and other foreign Patents Pending

MINOR in size yet a MAJOR new addition to STANDARD DIAL BORE GAGES

NEW #00 uses centering-size discs for checking bores from 1/4" to 3/8"

★ Designed for tolerances up to .005"
★ Sapphire tipped gaging plunger
★ Chrome plated centering-size discs assure long "precision-service"

YES, Standard Gage, pioneer of dial bore gages, has developed a still newer type of dial gage for quick, accurate inspection of small diameter bores from .250" to .375". The ultimate in precision gaging of small bores, STANDARD'S No. 00 is based on an entirely new "interchangeable disc" principle, surprisingly simple in design, easy to set and easy to use.

- Readily entered in bore
- Holds its setting
- Gives positive repeat readings
- High visibility dial graduations of .0001" are easy to read

Sapphire tipped gaging plunger and chrome-plated centering-size discs insure a long, trouble-free gaging life.

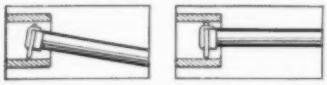
Patent Applied For
Enlarged diagram shows easy assembly of centering-size disc on plunger.
New centering-size disc
A turn of the knurled clamping nut releases centering-size disc or locks it firmly in place.

Photograph actual size

EASY "SIZE CONVERSION"

Conversion to various sizes in the range from .250" to .375" is accomplished by the quick interchange of centering-size discs on the same head by the one-step operation of turning a clamping nut. Positive locking action of this nut insures holding set dimension. Centering-size discs are furnished to suit dimensions of bore to be checked. No. 00 will check to within 1/16" of the bottom of a blind hole.

EASE OF OPERATION



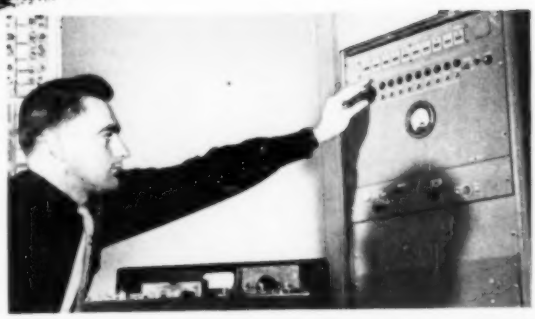
Gage is entered at an angle to allow extended plunger to clear the bore, then rocked to cause plunger to pass a square position while noting minimum reading on the indicator.

When ordering be sure to state nominal size of bore and tolerance desired

Now 8 sizes cover range of 1/4" to 16" in STANDARD'S line of Dial Bore Gages.
Write for new complete Catalog C showing these and other gages.

STANDARD GAGE CO., INC., Poughkeepsie, N.Y.

Thunder Hunters



Thunder hunting equipment on location near Madison, Florida. Loop antenna on truck picks up static. The engineer in top picture is watching the indication of a circuit which registers how often the static exceeds a given level.

Many new telephone circuits have two jobs to do—carrying your voice and transmitting signals to operate dial exchanges in distant towns. And an old-fashioned thunderstorm can interfere with both!

"Rolling static" comes from many storms over a wide area and can interfere with clear telephone talk. A nearby lightning flash makes "crack static" which, unchecked, plays hob with dial system signals.

So Bell Laboratories scientists go "Thunder Hunting" in the storm centers of the United States – "capturing" storms by tape recorders. Back in the Laboratories, they recreate the storms, pitting them against their new circuits. This method is more efficient and economical than completing a system and taking it to a storm country for a tryout. It demonstrates again how Bell Telephone Laboratories help keep costs down, while they make your telephone system better each year.

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Operations Research in Business and Industry

RUSSELL L. ACKOFF
Research Associate, Case Institute of Technology

IN THE August 5th issue of the nationally distributed Sunday Supplement, *This Week*, Lt. Col. David B. Parker gave his article on Operations Research the title: "Our Greatest Secret Weapon." A more conspicuous misnomer would be hard to find. First, there is nothing about Operations Research (or OR as it is familiarly referred to) that is secret; secrecy has been attached to some of the problems it has investigated, but not to the method itself. Secondly, it is not a weapon; it *is* a tool. A weapon is an instrument intended for combat; no such intention is integral to OR.

OR is also frequently referred to as something "new"; this is not so much false as misleading. Many aspects of the method have been used separately and collectively for a long time. OR is new, however, as a self-consciously formulated, organized, and institutionalized scientific procedure, and it is in this respect that it constitutes a very important scientific development.

Institutionalized OR began in Great Britain in 1940 during the historic Battle of Britain. The British High Command was faced with a critical problem: how best to employ their inadequate supply of planes, pilots, detection and communication equipment against the superior forces of the German air invader. With perhaps more hope than expectation the British military leaders called on a group of scientists to help solve the problem. The scientists were so successful that such assistance was institutionalized by the formulation of the first OR team. Many others followed quickly. At one time as many as 175 British scientists were engaged in such work. This country quickly followed suit; each branch of the military set up central agencies and field units to carry on OR. Military OR groups operated throughout the remainder of the war, and continued to do so after the end of hostilities.

In the last few years OR has received more and more civilian attention as the possibilities for its application to industry, business, and non-military aspects of government became apparent. In Britain the method has been used successfully in dealing with industrial and transportation problems.[1] Industrial and commercial possibilities are beginning to be appreciated in this country as well. The April, 1951 issue of *Fortune*[2] discussed the application of OR to industrial research. The December 1st issue of *Business Week* did the same. The National Research Council established a committee to explore these possibilities.[3] The Morse and Kimball book, *Methods of Operations Research*[4], has attracted considerable attention from industry and business. In Great Britain an association of Operations Researchers has been founded; it now publishes a *Quarterly Journal of Operations Research*. Many universities and research agencies have either set up, or are now considering plans for setting up OR facilities and training programs.[5]

At the end of the war, when a number of operations analysts returned to civilian research and teaching, they began to reflect on the significance of the method they had developed. Through verbal and written interchanges a definition was evolved which has found some (but not yet general) acceptance. It is: "Operations Research is a scientific method of providing executives with a quantitative basis for making decisions with regard to operations under their control."

This definition, informative though it is, does not distinguish OR from other kinds of research. Science has long been providing executives with quantitative bases for directing operations under their control. A conspicuous example is the use of statistical quality control methods for deciding whether or not a process is capable of conformance to design requirements.[6] No, OR is not distinguished either by its objective or its subject matter. It is distinguished by the methods which it employs and by the scope of problems its methods enable it to attack. But even here there is apt to be confusion for there is no aspect of OR's method which cannot be found in other kinds of research. The distinguishing characteristic is the combination of these principles of method into a comprehensive method of problem-solving.

Different operations analysts emphasize different research methods, and hence practice OR differently depending on their emphasis. (But, as we shall see, a basic cohesive methodology lies under these apparent differences.) The mathematically oriented operations analysts emphasize "quantification" as the key to OR. The physically oriented emphasize the use of physical models and concepts. The statistically oriented emphasize the use of (different) statistical methods; and so on. Yet, as indicated, there is an underlying common core of research principles. Before we consider these principles in detail, it would serve us well to examine the setting against which they will be viewed.

OR, like all research, is concerned with finding solutions to problems. It realizes that there is seldom, if ever,

one and only one solution to a problem, and that a "perfect" solution is something ideal rather than real. Solutions vary in the efficiency with which they serve the objectives and goals which form the basis of the research. OR, more than any other type of research, is concerned with the development and use of *measures of the efficiency* of a proposed solution to a problem. This concern with measures of operational efficiency of proposed solutions has made the operations researcher into a sort of scientific architect. In fact, the relationship between operations researchers and other types of industrial and business researchers is much like the relationship between the architect and engineer.

The architect, in designing a building (which is a proposed solution to a shelter-problem), is dependent on the technical information and advice that various kinds of engineers can provide. Keeping the many functions the building must serve in mind, the architect coordinates all the engineering information and his own observations into a design or model for the building. This design procedure is carried on by the manipulation of symbols, usually graphic. The design enables him to evaluate the interrelationships of the component parts and to evaluate the whole before construction begins and changes become costly.

The operations analyst is likewise dependent on the information and advice that research specialists can provide. He cannot and does not seek to replace them any more than the architect seeks to replace the engineer. The operations analyst attempts to coordinate this information into proposed solutions—designs—whose efficiency he can determine before costly commitments are made. This coordinative and design role of the operations analyst enables him to take on more complex problems than can the research specialist. He can attack problems which are broader in scope and interdepartmental in character, hence his particular usefulness to the executive.

The concern of the operations analyst with producing measurably efficient solutions to problems has resulted in the formulation of principles of research procedure whose function it is to assure efficient research. An understanding of these principles can yield an appreciation of the possibilities of OR in industry and business.

We shall consider five such principles. By way of a brief introduction, they are:

(1) *The Principle of Measurement.* Wherever possible measure the properties of all variables that count, and the relationships between them. Where measurement is not possible, make it possible.

(2) *The Operational Principle.* Take into account not only the one who makes the final decision on a course of action, but also all those who carry out the decision and are affected by it. The interactions between all those involved and the role of the environment and instruments must be viewed dynamically, as a changing system, not as a static one.

(3) *The Feed-Back Principle.* Do not end the research with the selection of a proposed solution. Evaluate the proposal in use. Where it is not good enough, conduct further research. This involves a continuous interaction between all phases of the research and operations, and continuous communication between all parties involved.

(4) *The Cooperative Principle.* Include on the research team representatives from as many areas of science as possible. Where possible, even include representatives of disciplines which do not appear to be directly involved with any aspect of the problem.

(5) *The Practical Principle.* Evaluate every phase of the research relative to the research objectives. This requires an explicit formulation of the objectives of the decision maker and all those to be affected by his decision.

Now let us consider each of these principles in detail.

THE PRINCIPLE OF MEASUREMENT

The emphasis on measurement is characteristic of most discussions of OR. This emphasis may seem peculiar in light of the fact that science has always sought to measure where possible and, where measurement is not possible, to make it possible. Science has long recognized that quantitative data are useful in a wider range of circumstances than are qualitative data. Then what is new in the principle?

There is nothing new in the principle, but there is something new in the way in which it is practiced. OR self-consciously and deliberately attempts to invade various non-quantified areas.

First, areas where common sense, which generally operates on qualitative data, has seemed adequate. For example, during the recent war, emergency situations arose which exposed the inadequacy of common sense in many domains in which it had been considered to be more than adequate. Specifically, it had long been considered a matter of common sense that when one is confronted with the problem of deciding which of two devices is the better for performing a given task, one should ask those who are experienced in the use of both devices for their opinions. During the war reasons appeared for doubting this assumption. The Franklin Institute in Philadelphia set forth on a set of experiments to determine the relationship between such expressed preferences and actual performance with regard to some naval equipment.[8] Both the preferences and the performances were subjected to measurement. Performance frequently was found to contradict preference.

OR tries to unearth assumptions such as these and subject them to critical evaluation in quantitative terms. In this respect OR is completely agnostic; it attempts to minimize the number of common sense assumptions to which it must commit itself.

Before leaving this point, one modern statistical development should be mentioned. Techniques have been developed for measuring the relationship between two or more sets of qualitative data.[9] For example, suppose two inspectors are given ten items to rank in order of their quality, where these inspectors must resort to qualitative judgments. The results might look as follows:

First Inspector's Ranking	Second Inspector's Ranking
1	4
2	7
3	2
4	10
5	3
6	6
7	8
8	1
9	5
10	9

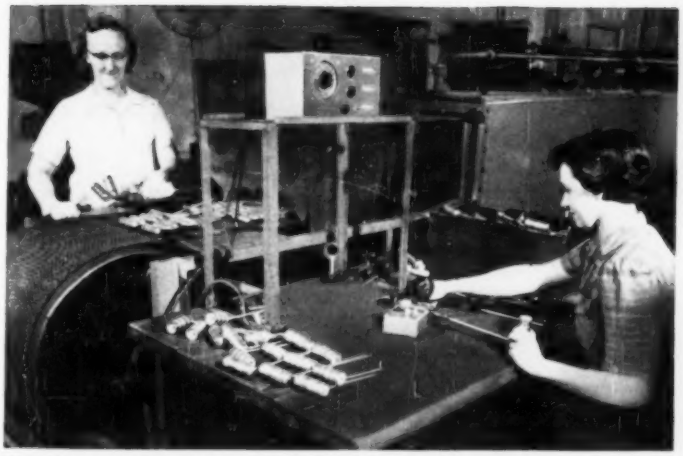
This means that the item ranked first by one inspector was ranked fourth

by the other, and so on. By a very simple computation we can determine a measure of agreement for these rankings, which in this case does not turn out to be statistically significant. Such a measure applied to qualitative data indicates that the judgments do not agree even though the objects inspected are the same.

OR brazenly attacks areas in which quantification is very difficult because there appear to be "too many" variables to handle comfortably or keep under control. OR exploits new mathematical and statistical techniques and instruments in order to come to grips with problems whose complexity is apt to frighten others. OR does not cling to the 19th century's ideal experiment: one involving a single independent variable, a single dependent variable, and all the others held constant. For example, by the use of a statistical method called "the analysis of variance"[10] and the new computing machine, the UNIVAC, it is possible to study a problem involving up to one-hundred variables, and to determine the interactions between any possible combinations of these variables. Such a complex analysis would have been unthinkable but a few years ago.

All the devices which OR employs are not so complex. For example, recently we were confronted with a problem of finding measures of probability which were defined by a very complicated integral. The approximate solution of this equation for each set of values of the variables required about one man-day. By the use of "circular probability paper" the equation was solved for each set of values in about fifteen minutes by one man.

OR has relied heavily on sampling methods in order to simplify predictions and analyze problems. Many of us have come to realize that many industries and businesses are plagued, not by a lack of data, but by too much uncoordinated information. Sampling processes not only cut down on the cost of gathering data, but also organize coherent methods of formulating data that are quickly intelligible to policy makers. Thus, in some industries, it is extremely costly and awkward to make daily estimates of earnings on the basis of a complete auditing, but sampling techniques are often available that are much cheaper and at the same time provide an accurate estimate of their reliability.[11]



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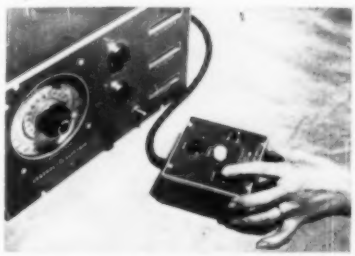

G-E Continuous Sampling Monitor (left) with control station. Note small space requirement for the two units.

GENERAL ELECTRIC

687-88

THE OPERATIONAL PRINCIPLE

For most of the 19th century, science's conception of nature was essentially a static one. The scientists were interested in taking snap shots of small portions of nature. Today scientists take continuous motion pictures of as much of nature as their lenses can include. The result is that most of the new ideas in science are dynamic and synthetic rather than static and analytic. We study multiple interactions between many elements and groups of elements in physical and social "fields" and "systems"; we study continuous processes such as entropy and evolution in all fields. We are becoming increasingly aware of the fruitfulness of applying this orientation to practical problems as well as to theoretical ones. Cybernetics,[12] the science of control through communication, is an outstanding example of such an application.

OR has self-consciously applied this dynamic orientation to the study of operations performed by men and machines. It does not concentrate on simple action-reaction or stimulus-response situations, but attends to complex *interactions* between individuals and groups, animate and inanimate. OR does not seek to abstract ideally simplified situations from reality; it comes to grips with reality in all its complexity.

One dramatic illustration of this point is to be found in the military applications of OR. In employing any military tactic or strategy the enemy can be expected to react. This reaction is called a "countermeasure." We, on the other hand want to anticipate this reaction and take it into account in our planning. We usually do this by selecting the operations so that possible counter-measures can themselves be countered. This means that a tactic or strategy cannot be taken as static but must be taken as dynamic. All possible responses of the enemy must be swept into the problem, and hence into the solution.

The failure to so conduct research frequently leads to costly mistakes. One industrial case in point is that of a large manufacturer who had researchers investigate the problem of what kind of plant should be built to manufacture a new high-precision instrument. One of the researchers' recommendations was that the work space of the plant should be windowless and that an even artificial light be provided. This, it was argued, would produce more precise work. The factory was built, and though the quality of the product was high, the rate at which it was produced was much lower than was anticipated. Researchers were again called in. They found, among other things, that an unreasonable amount of time was being spent by the workers in the washrooms. They found that the frequent prolonged visits to the washrooms were due to the fact that the washrooms had windows and the workers could look out to see what it was like outside, and relieve their claustrophobic feelings. The result was that holes were punched through the walls of the work space and windows were inserted.

This difficulty was unnecessary. Researchers oriented toward the whole operation and its field would have avoided this error. OR self-consciously adopts this orientation. It is concerned with operations, with operators, that which is operated on, that which is used in the operations, and the environment within which the operations take place. OR is not unique in this emphasis, but it is more self-conscious in this regard than most research.

THE FEED-BACK PRINCIPLE

Research is usually conducted like a horse race. There is a starting line, a track to be covered, and a finishing tape. There is one start, one dash, one finish, and, in an honest race, no cooperation between the contestants. Perhaps this is a forced analogy, but it helps to emphasize the nature of an important change in our notion of proper research procedure. We are beginning to think of research as a continuous process, an on-going process which does not win or lose after one exhausting expenditure of effort. That is, we are beginning to think of research as a communicative process, one which involves that particular relationship we have come to know as "feed-back." Consider a simple example of a feed-back process: the ordinary thermostat that controls the heating system in a house. The room temperature drops and affects the thermostat. The response of the thermostat affects the heating system which in turn raises the room temperature. The thermostat then responds differently and affects the heating system differently, thereby converging on a desired room temperature. We have, in effect, a "cycular" flow of information. Research should involve such a flow of information. OR acknowledges this fact and exploits it.

The consumer presents a problem. The researcher begins to design a method for getting a solution. The design process forces clarification of the problem by the consumer, which clarification requires modification in the research design. The design is tentative, and itself develops by an interaction between various decisions of various research planners. A research plan evolves and is put into operation, usually on a small scale at first. Putting it into operation means applying it to the processes involved in the problem. This is not the end, for the research operations themselves affect the process under study. The effects are studied and characterized. These suggest modifications in the research design which leads to further modifications in the processes. Thus there is a flow of information and action from research to process. This feed-back process itself converges on producing the desired result. The solution is approached by stages of research operations.

A few analogies might clarify this aspect of OR. Consider a social problem which requires governmental legislation. The legislation is a proposed solution. Putting it into effect requires an administrative program. The program as administered is eventually evaluated in the courts. These judiciary evaluations eventually modify the legislation, which sets off a new cycle.

Or, again, in the manufacturing process, specifications for a product are prepared (legislation or design). A productive process is established and put into operation (administration or application). A quality control procedure evaluates the results (judiciary or evaluative). In light of these modifications either the specifications or the production process is modified, or both, and hence the quality control method is changed; and so on until a satisfactory product is produced.[13]

The feed-back between stages of operations research involves an intensive communicative interchange between all those involved in the problem and its solution. Those involved are not only the researchers; OR urges frank and frequent contacts between research staff, the policy-makers, and all those who will be affected by the research. OR tries to get away from the procedure whereby a central agency writes to the research laboratory requesting

certain information, the laboratory director passes on a request to a professional who next tells a technician what to do, and subsequently asks a statistician to analyze the results. The answer passed back up the ladder to the central policy agency often has little or nothing to do with the felt need that initiated the original directive. For this reason OR has tended toward team research, where all interested and affected personnel can discuss the research problem on a cooperative basis.

This was one of the most important factors in the military success of OR. The operations analyst had free and direct access to military personnel of all ranks. The analyst was a free-floating agent who could enlist the cooperation of the private on the front line or the commanding general. OR must include the whole theatre of military or productive operations in its laboratory.

THE COOPERATIVE PRINCIPLE

From its very beginning OR found it efficient to include representatives of different scientific disciplines in its research teams. Team research is, of course, nothing new. Little research is being conducted anymore by the isolated scientist in his secluded laboratory. We often find teams composed of representatives of the same science, such as a group of doctors, or a group of physicists. Increasingly common are teams made up of representatives of different but closely related fields. It is not uncommon to find mathematicians, statisticians, physicists, and chemists working on the same project, or to find electrical, mechanical, and civil engineers cooperating in research. But it is less frequent that we find all bands of the scientific spectrum represented on a single team. Where such representation is found, it is usually due to the fact that the problem clearly requires such cooperation. For example, The American Society for Testing Materials set up a task force several years ago to study methods of determining consumer interests and adjusting production standards to these interests. The solution of the problem involved knowing a great deal about what the consumer wanted, what he needed, and how these needs could be translated into production specifications. It also involved examining methods for getting acceptance of the results of the study by producers of consumer

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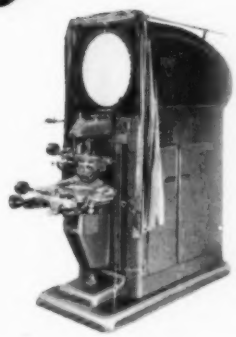

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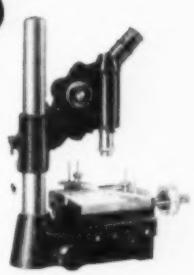

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goods. The task force, of necessity, had to include a production engineer, psychologist, social scientist, statistician, and lawyer.

Such need for interdisciplinary cooperation, where the problem obviously crosses several fields, can pretty much take care of itself. The concern here is with situations where the problem appears to belong to some restricted area, for here it is most important to realize that interdisciplinary cooperation can function effectively. There is no mystery about this apparent contradiction; it can be explained in light of what we have already said about OR.

OR is concerned with processes; that is, systems of behavior. We have become increasingly aware that such systems are operative in all scientific areas, and moreover that they are similar. Let me refer to the most dramatic case in point, the development of cybernetics.[14] Cybernetics studies the transmission of information in situations involving the control of operations. The general components of this process can be found in electronic devices, in an animal's nervous system, in an industrial plant, in a department store, in a relationship between any two individuals or two nations.[15] In the development of cybernetics, representatives of all the sciences were involved, as Norbert Wiener acknowledges. It was only through such cooperative effort that so general a picture of the communicative and control processes could be developed. All this has helped emphasize the fact that most processes which appear to apply to only one science have their analogues in all other sciences. Each field has worked out a technique for study of this process, and in many cases the techniques worked out for analogous processes in different fields are not much alike. Hence there is considerable potential aid which can be derived from other disciplines by virtue of the difference in their methods of attacking these general processes.

Let me refer to several examples to make this point clearer. A problem arose in agricultural biology, one of testing the fertility of seeds. It would do no good to set up a laboratory in which fertility could be observed, first because of the multiplicity of variables, and secondly because the seeds which are fertile under laboratory conditions need not be so in actual farm conditions. Yet how could the multiplicity of variables entering into the seeds' behavior be handled? R. A. Fisher,[16] a British statistician, worked out a method, the analysis of variance, to which I have already referred. Numerous applications in completely unrelated fields have been found for this method. But, even so, this powerful scientific instrument is not being exploited to its fullest because of the paucity of interdisciplinary communication.

To take another example: a group of engineers, physicists, and chemists in an ordnance laboratory were worried because they were not quite sure how best to test the sensitivity of primer caps. The techniques of sensitivity testing are not obvious. Now it might seem peculiar, but they turned to the biologist for aid, because it turns out that the biologist probably knows more about sensitivity testing than anyone else. A considerable theory and practice of sensitivity testing had been developed for many years in the area of bioassay.[17]

For a third illustration, we could consider the work of von Neumann and Morgenstern on games of strategy and economic behavior.[18] In this work they provided methods for studying processes now quite generally recognized to be operative in all fields. These and many more examples to which I could refer all emphasize that each science is observing the same drama, but is seeing this same drama enacted by different casts.

To bring out the full implication of the Cooperative Principle let us consider a specific example in some detail. I was recently involved in a symposium which was attempting to determine whether or not psychoanalytic method is scientific. One of the bases for deciding whether or not it is, the psychoanalysts argued, is to find out whether or not there is any consistency in psychoanalytic diagnosis. But here is the rub, they said, a rub much like the indeterminacy situation in quantum mechanics. In the psychoanalytic diagnostic process the patient is changed. His symptoms as well as his ailment are affected. Hence a second diagnosis of the *same* patient is impossible in the sense that the patient is no longer the same. This fact, the psychoanalysts argued, precludes the possibility of any measurement of their diagnostic consistency.

This problem struck me as being almost identical to one I had helped tackle while working with the United States Bureau of the Census. The problem there was to determine how consistent census interviewers are.[19] Ideally we would like to have had each interviewer question each subject many times. The difficulty was that once a person had answered a set of questions, he changed and was no longer the same subject if reinterviewed with the same questions. A method was developed to handle this problem, one which seemed to me to be directly applicable to the psychoanalytic problem.

Suppose we take a group of psychoanalysts and a group of patients. We have no idea beforehand how the various mental ailments are distributed among the patients. But if we randomly assign patients to the analysts, then each analyst would have what could be considered to be a representative sample of the total population of patients. Some sampling error would be involved, of course, but this creates no great difficulty. Each psychoanalyst could be characterized by the distribution of ailments which he discovers. If there is consistency in diagnoses, the distributions of the various analysts should be the same. Statistical tests are available which would enable us to determine whether or not this is the case.

Some will have recognized that analogous problems arise in their own fields. An obvious case is the situation in which we want to determine whether inspectors on a production line are consistent in their judgments, where the inspection process results in the destruction of the objects inspected. Here too we cannot give the same objects to different inspectors to get their evaluation of it. But we can compare the inspectors by a method similar to the one I have described for comparing psychoanalysts.

It should be obvious by now that accessibility to the methods developed in all the various sciences is a necessity to the OR team. In addition to representatives of the various sciences (representatives who are familiar with the methods of their respective sciences), it has been found invaluable to include a specialist in scientific method itself; that is, a methodologist.[20] His in-

clusion pays off in several ways. For example, in addition to being confronted by problems which can be solved by applying methods already available in various sciences, OR is also confronted by problems for which no existing methods are adequate. For some OR problems, or phases of these problems, new methods must be developed. The methodologist is of particular importance in such situations.

What is a methodologist? He is a scientist whose subject matter is the method of science itself. Though the science of methodology is a new science, the study of scientific method is as old as science. But until recently this study was not taken to lie within the domain of science; it was taken to be a branch of philosophy, the philosophy of science. Earlier in this century, however, both John Dewey [21] and E. A. Singer, Jr.[22] demonstrated the possibility of studying scientific method in a scientific manner. With their demonstration the science of methodology was born and is now a thriving youngster.[23]

OR, as I have indicated, is confronted by a large number of methodological problems under circumstances which stimulate self-consciousness with regard to them. For this reason, the development of OR will increasingly involve the use of scientifically developed principles of methodology.

OR has done a great deal to break down the barriers between the various sciences, but it has only begun. It is fighting one of the strongest traditions of science, one reflected in the departmental structure of universities where departmental autonomy protects the sterile isolation of the scientific specialist.

There are few who have seen the formulation of the Cooperative Principle who do not verbally agree with it. But so few of those who "accept" this principle practice it. We should not argue in specific situations that there is no real need for representatives of other disciplines. The failure to include the other sciences when they are needed is generally much more serious and more likely to occur than the inclusion of other sciences when they are not necessary. OR has found that the most successful procedure is to insist on including other disciplines even when the need is not clear at all, simply because there is virtually

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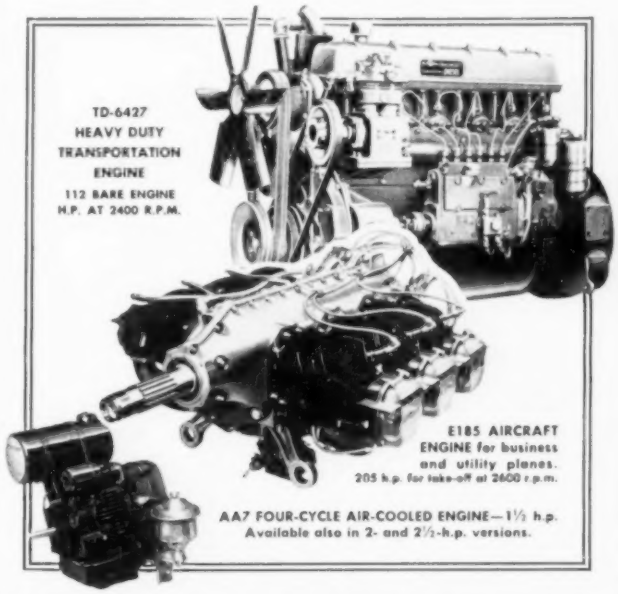

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no danger and often much profit in such a procedure.

THE PRACTICAL PRINCIPLE

To say that OR is practically oriented is not very informative since the concept of "practicality" is such an ambiguous one. Let us try to clarify it, particularly as it applies here. OR is a means used by policy makers to help them select a course of action. Whatever the course of action, it is designed to have some effect on people and things. Thus, the decision maker and those affected by his decision can be considered to be consumers of OR; the decision maker (or policy maker) is *the immediate* consumer, those who carry out the decision are the *intermediate* consumers, and those who ultimately consume or are affected by the services and products provided, are the *ultimate* consumers. In the military situation the immediate consumer is the staff unit for whom the research is being conducted. The intermediate consumers are the friendly troops who carry out the orders of the staff. The ultimate consumers are the enemy troops and their civilian population. In the industrial or business situation the immediate consumer is the policy making body (board of directors, plant manager, etc.). The intermediate consumers are the immediate consumer's employees. The ultimate consumers are those who "use up" the products or services supplied, and the competitors. In the military situation direct communication with enemy troops and civilian population is virtually impossible. This is not so in the case of industrial and business applications of OR, and herein lies a very important advantage for the non-military use of OR. In business and industry direct communication with the ultimate users of the products and services is possible.

For example, we have already referred to the problem of countermeasures, that is, the possible reactions of the intermediate and ultimate consumers to the immediate consumer's decisions and actions. The military could only study its own troops directly, and it did this with considerable success. It could not do so with the enemy. No such restriction applies to industry and business. Free communication with competitors is, of course, often impossible, but not so with the users of the product and services provided. These users are generally willing to cooperate with industry and business since their respective interests are not necessarily in conflict, as they are in the military situation.

The reintroduction of the countermeasure problem is a diversion from the present theme, the "practical" or what we might call the "consumer orientation" of OR. The significance of this orientation becomes clear when we realize that OR is itself a set of operations with a set of objectives. The objectives of a particular operations reseach project are, to be sure, a function of the objectives of the various consumers. As a process, or set of operations, OR's efficiency can be determined relative to its and the consumers' objectives. That is, it is quite possible to institute a procedure for controlling the quality of the research itself, a procedure of continuous self-evaluation relative to the research objectives. Just as quality control is used in the production process to assure a higher quality product, so quality control can be used on the research process to assure its yielding more efficient solutions.

In order to exercise control over the quality of the research, the objectives of the research must be explicitly formulated, and hence the objectives of the various consumers must also be explicitly formulated. The Practical Principle requires such formulation. Hence OR not only deals with the practical problems of others, but it approaches its own procedure as a practical problem.

The failure to formulate explicitly research objectives is frequently a costly and grossly inefficient mistake. Let me illustrate this point by another experience I had while serving as a consultant in the Bureau of the Census. We were engaged in preparing the "Post-Enumeration Survey." This is a sample survey, intensive in character, which is used as a basis for estimating the errors in the decennial census. One of the census questions being checked involved determining the number of rooms in a dwelling unit. In the Reference Manual prepared for the decennial census enumerators a lengthy definition of "room" and numerous illustrations were provided. Our task, however, was to define "room" for the post-enumeration interviewers in a much more precise way so that errors could be reduced. Offhand it seems like an easy task to define a room. At least it seemed so to many of the census experts I asked to do so. The general pattern of the conversations went as follows: First they expressed annoyance at being bothered with such a trivial problem. Then with considerable coaxing they would offer a definition like this: A room is a space enclosed by four walls, a ceiling, and a floor. I asked an obvious question. "Can there be a circular room?" They said there can be such a room and modified their definition to "an enclosed space." I then asked whether they would consider a closet to be a room. They said, "No, the space must be large enough for human occupancy." I pointed out that there are closets large enough for a person to walk into. "Yes," they said, "but not large enough for normal living purposes." I asked what they meant by "normal living purposes." This exchange continued, in general, until my informant lost patience and tried to settle the question with, "This definition may not be absolutely precise but it will produce results accurate enough for our purposes." This was the opening for which I waited. What were "our purposes"? It turned out that no one was quite sure. This being the case, how could we determine whether or not the results were accurate enough for our purposes? Further probing yielded some tentative formulations of purposes for which the question was asked, but this was rather late for such explicit formulations to be made. The point is that scientific definitions should be instructive to the scientific observer. It is in this sense that definitions should be operational; they must direct operations. But whether or not they specify the correct operations depends on how well these operations serve the objectives of the research. Efficiency in serving research objectives is a criterion which should be self-consciously applied in evaluating all conceptualization in research procedure.

One of the most striking examples of the need for evaluating research decisions is to be found in modern statistical procedures. The development to which I refer is based on the work of Neyman and Pearson,[24] and was explicitly formulated by Wald.[25]

In preparing for a statistical analysis at least three decisions must be made: (1) How many observations should be made? (2) How much

error should be permitted? (3) What type of statistical test should be applied? Wald's great contribution to statistical theory lay in his showing that these decisions can only be made relative to the risks (costs and losses) they involve relative to the pursuit of the research objectives. Put crudely and briefly, each set of decisions regarding these three questions can be evaluated with respect to the seriousness of the mistakes they are apt to produce and how likely they are to result in these mistakes. In effect, Wald demonstrated that we should make these statistical decisions on the basis of which selection minimizes the risks relative to the research objectives. Specifically, he suggested that the best set of decisions is that which minimizes the largest risk that must be taken. This is the well-known "minimax" principle, minimizing the maximum risk.

Most users of statistical methods make their statistical decisions on the basis of convention and never ask themselves or anyone else whether these conventions are efficient. They do not self-consciously evaluate their methods. This is what the Practical Principle demands, and OR makes every effort to satisfy this demand.

SUMMARY

Now that we have considered the underlying principles of OR we can formulate an over-all picture of the method. This picture must necessarily be brief, but it will serve to bring together the various points made.

In OR, as in any research, the problem must be formulated. The complete formulation of the problem consists in making explicit the various objectives involved, in particular, those of the immediate, intermediate, and ultimate consumers. The various operations must be formulated relative to the objectives which must be satisfied. Formulation of alternative operations and objectives requires continuous communication between the researchers and the various consumers. In addition to consumers, the instruments involved and the environment must be taken into account, and these should be characterized dynamically (not statically). That is, how do all the variables and objectives change over time? Where possible all the variables and their interrelationships should be expressed quantitatively. This task requires the cooperative effort of at least several content-areas of science and the methodologist.

Necessary for the evaluation of the possible solutions is the weighting of the various objectives according to their relative importance so that an over-all evaluation of the alternative proposed operations can be made. This involves taking into account possible errors that can be made, their seriousness, and their likelihood of occurring. A special type of interference must be taken into account, that which we have called "counter-measures." The conceptualization of these processes must yield as many of the pertinent variables as possible.

The actual evaluation of the alternative operations requires a great deal of information. Some of this can be obtained from existing sources, but only with effective communication and cooperation between many fields. Where needed information is not available, contfolled experiments must be designed and conducted. The eventual evaluation of the operations involves not only information obtained in these ways, but also involves a set of assumptions. These must be made explicit so that their implications are clear, particularly with respect to limitations on the applicability of the results.

None of these research decisions is distinct and independent, and they have no necessary ordering in time. They go on simultaneously and interact on one another. Eventually they converge on a tentative solution. The proposal leads to its application and evaluation. Where the proposed solution is not all that was expected, this information is put back into the research and a new tentative solution is selected. This process continues until a satisfactory result is produced.

The sum total of all this concern with research principles and procedures is that OR provides the policy maker with a method for obtaining a sound scientific basis for making policy decisions at any level. OR makes scientific management a reality. It replaces neither the policy-maker nor the research specialist. It coordinates and supplements the work of the research specialist in such a way as to provide the policy-maker with more than the usual intuitive basis for directing processes of production and distribution of goods and services.

The important question facing the policy-maker is not "Can I afford to try Operations Research?" but "Can I afford not to try it?"

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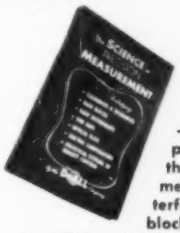

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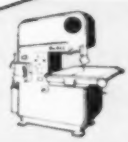

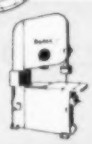

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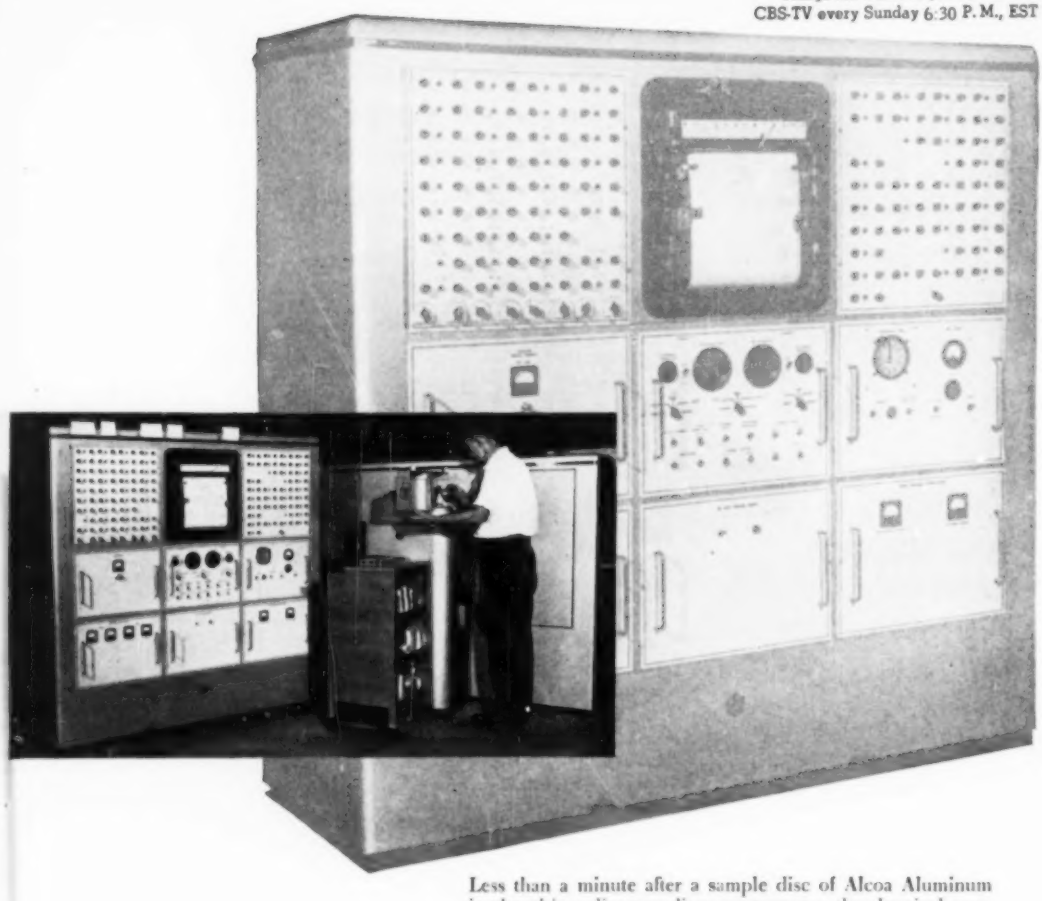

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INDUSTRIAL QUALITY CONTROL

Engineering for Low Product Cost and High Product Quality at the Western Electric Company*

A. C. JONES

Works Engineer of Manufacture, Hawthorne Works, Western Electric Company, Inc.

PRODUCT quality and its control has long been of paramount importance in the policies and operations of the Western Electric Company, as it has been in many other companies. There is every evidence to support the view that product quality is assuming more and more importance throughout all industry. You have but to scan the pages of our trade journals, magazines, television screens, and other sources of advertising to observe that product quality is rapidly becoming the key note of our national advertising. The very rapid growth and fine work of the American Society for Quality Control since its formation, less than six years ago, is further recognition of the growing importance of product quality and its control.

As it has grown in importance, it has likewise grown in scope, and I think it might be well to examine briefly the broader concept of quality as it is viewed today. I recently learned of a letter which an author of an article on quality and its control received from a plant manager in the Orient, expressing deep appreciation for the help he had received from the article. He went on to say in effect that "I have been very successful in applying the procedures for I have already been able to cut my inspectors in two". While this may be viewed as a very worthwhile result by those workers who at times have felt that they were at the mercy of a critical inspector, it is, of course, a misstatement of any of the attributes of quality or the purposes of its control. There still exists the view in some quarters that the quality of a product is solely determined by the extent to which it conforms to specification requirements. This criteria of quality likewise falls far short of what should be expected in a high quality product. The customer is entitled to expect much more than this, for to him it is more important that the product afford serviceability, durability, reliability, good appearance, and should represent a proper balance between price and quality. It is this phase of the general subject of quality and its control that I would like to discuss, specifically as it relates to our engineering achievements at the Western in the interest of low product costs and high product quality.

QUALITY AND COST

Everyone, no doubt, has encountered products where quality and price have gotten out of balance, but that does not necessarily mean that they cannot be kept in balance. To illustrate my point, I should like to use an example.

There is in the transmitter of the telephone set a part which is plated with gold for transmission reasons, and there is a minimum requirement for thickness of this plating. If the thickness of the plating were doubled, the cost of the part might be increased about in the same proportion, but the improvement in the function of the part would hardly be measurable. A condition of this kind might support a high price, but it does not maintain the proper relationship of quality and price.

Very often the view is expressed that a high quality product of necessity must be a high priced product. I would like to challenge that view and supported by the evidence of many years experience of the Western Electric Company, establish the contrary view that low production costs and high product quality need not be in conflict. The factors which go to develop high quality stem from many sources, some affect manufacturing costs and others do not. Management's policy in regard to quality is an important one, and in itself need not affect manufacturing costs. If high quality is the goal of management, then everyone in the organization from the president to the shipping clerk must be quality conscious, and each make his or her contribution to attain this goal. It would be a very difficult assignment to appraise accurately the contribution of each of the various occupations or each of the factors on which high quality and low costs are dependent—the product designer, the manufacturing engineer, the supervisor, the machine or tool designer, the man at the machine, the woman in the conveyor line, the inspector, the quality control procedures, employee morale, and efficiency, or many other contributing factors that could be listed. I believe, however, we at the Western are in agreement that, under the organization which we have, the manufacturing engineer has a great opportunity through his efforts to effect low manufacturing costs and high product quality.

OBJECTIVES OF WESTERN ELECTRIC ENGINEERING

Just a word about our set-up at the Western. We are the Manufacturing Branch of the Bell System. Our products are designed by the Bell Telephone Laboratories. In the Manufacturing Branch of the Company we have an organization known as the Engineer of Manufacture, which is well staffed with technically trained men, whose job it is, as the name of the organization implies, to engineer our products for manufacture. A three-fold result is expected from these engineers—

1. Low manufacturing costs
2. High quality of product
3. Improved working conditions for employees.

While, as previously stated, our products are designed by the Bell Telephone Laboratories, the first contact of the manufacturing engineer with the product takes place in the very early stages of design. With his manufacturing experience he is very often able, by working with the product designer, to suggest features that have an important bearing on manufacturing costs and product quality long before the product goes into production. His second opportunity to influence quality is in plan-

*Presented before a luncheon session of the Sixth Midwest Quality Control Conference at the Hotel Sherman in Chicago, Illinois, November 16, 1951.

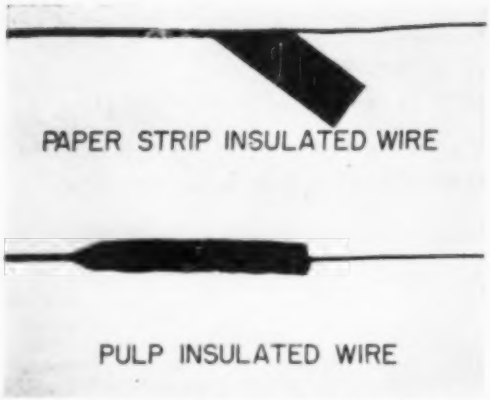


Figure 1—**Paper Strip Insulated vs. Pulp Insulated Wire**

ning for the manufacture of the product. The determination of the most suitable processes and methods of manufacture involved and the sequence of these operations, the selection of the best machine for the purpose, the right type of tool and gauge required, the arrangement of these facilities in the shop, the grade of labor to be employed, all of these functions for which the engineer is responsible have an important bearing on the cost and quality of the product. His third opportunity comes in introducing changes in facilities and methods as he is able to develop or discover new and improved ones. There can be no fixed formula that can serve the engineer in carrying out these assignments. Experience, of course, is a big factor. One helpful thing for him to bear in mind, however, is expressed in the old adage "To err is human", and wherever he can mechanize an operation and eliminate or supplement the human element he invariably has contributed something to the quality of the product.

A policy which we have adhered to religiously at the Western is that no changes are introduced in an effort to reduce costs that in any way will impair the quality of the product. This may appear to be a serious handicap for the engineer whose progress is determined by his ability to develop and introduce improved methods of manufacture. This has not been our experience, for we have found that when the engineer has arrived at the best way to perform an operation or manufacture a product, invariably the result has been an improvement in the quality of that product. I might also add that there have been many instances where the engineer has undertaken to improve the quality of a product by a change in the method of manufacture, and has obtained the dual result—improved quality and lower costs. That is why I maintain that high quality and low costs are not in conflict.

SOME EXAMPLES

1. Insulating Exchange Area Cable

I would like to cite a few cases from our experience where the accomplishments of the manufacturing engineer support this contention. I would like to start with one affecting one of our most important products with which you are all more or less familiar—exchange area cable. This cable, as the name implies, is that cable which connects your telephone to the telephone exchange and that exchange to other exchanges in a given area. You have observed it being drawn through manholes to be installed under the city streets, you have seen it suspended between poles, or you have seen it on reels awaiting installation in some neighborhood. This cable is being produced at an annual rate of 60,000,000,000 conductor feet and varies in sizes from 12 conductors up to 4242 conductors. Each conductor consists of a bare copper wire insulated by means of a paper covering. This covering was formerly applied by spirally wrapping a ribbon of paper around the wire as illustrated by the top view in Figure 1, and later by depositing wood pulp directly on the wire before converting it into paper, as shown by the lower view in Figure 1. The first method was performed on a paper insulating machine, shown in Figure 2. The paper is taken from a supply coil and spirally wrapped around the wire as the wire progresses through a revolving head to a take-up reel. This method proved to be quite satisfactory as long as the wire sizes were relatively large and production comparatively small. It was inadequate, however, as the trend in cable design called for smaller conductors, and the demand for cable greatly increased.

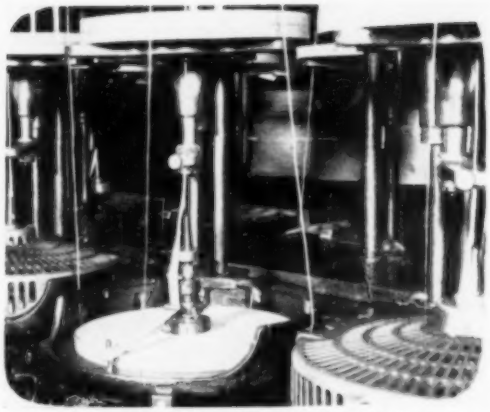


Figure 2—**Machine for Insulating Wire with Paper**

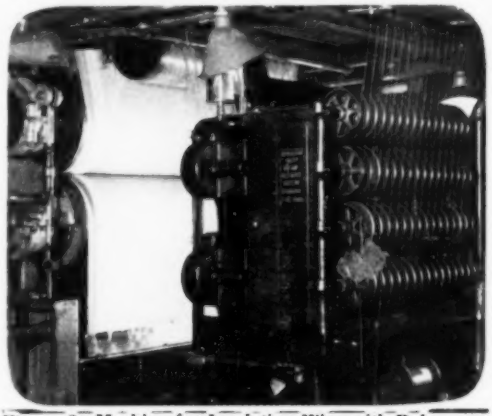


Figure 3—**Machine for Insulating Wire with Pulp**

The engineer undertook the development of a more

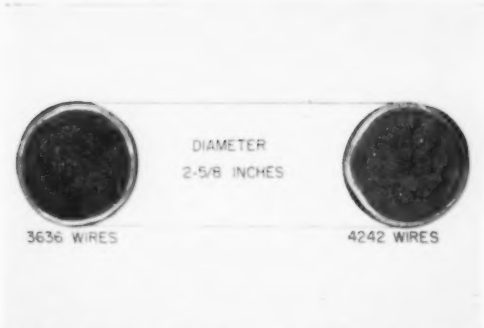


Figure 4—**Increased Cable Capacity with Pulp Insulated Wires**

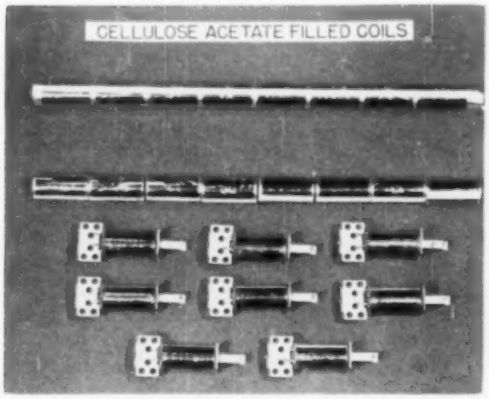


Figure 5—**A General Type of Coil Structure at Western**

rapid method of insulating the wire. Briefly, the improved method is that of mixing wood pulp and water to a consistency that permits depositing the pulp by means of drum type rollers on the bare wire in the form of a ribbon. The second step in the operation includes passing this pulp ribbon and the wire through a polishing head which reshapes the pulp deposit on the wire to form a smooth cylindrical sleeve incasing the wire. This machine, shown in Figure 3, was developed to coat 60 conductors at one time at about the same speed as the former machines covered one conductor. The advantages of the new method costwise can be summed up by this comparison—

One operator now produces the output that was formerly produced by six operators.

The cost of the wood pulp material is only 20% of the cost of the former paper used.

The amount of lead required for the outer sheath was reduced 10%.

The machine investment was reduced about 25%.

We have 25 of these machines in operation at the present time, and the aggregate cost advantage of the present method over the former method under conditions as they exist today represents an improvement of 25%.

Let us now turn from the economic aspects of this development to the improvements in quality which

Figure 6—**Coil Winding Machines at Western**

followed. There were two principal factors of improvement, the first being a stronger covering on the conductor which permitted higher speeds in subsequent operations than the former insulation would permit, and second, because of the more uniform and more complete coverage of the wire, the insulation properties of the conductor were greatly improved. The improvement in the mechanical characteristics of the conductor as the various processes were perfected ultimately permitted a reduction in the thickness of the insulation. This, of course, reduced the diameter of the conductor and the number of conductors that could be placed in the cable sheath of a given size was increased as much as 25% in certain of the cables. In the case of the largest cable we make, an increase from 3636 conductors to 4242 conductors in the same size sheath was made possible by the improved insulation, as lilustrated in Figure 4. This improvement was important to the telephone companies, as it enabled them to utilize the added number of conductors without increasing the number of cable ducts.

2. Winding Electromagnet Coils

Another case which I should like to tell you about briefly is a method of winding electromagnet coils which are used in large quantities in the telephone business. Figure 5 gives an idea of the general type of coil structure that we use, although there are hundreds of different coils varying in diameter, length, number of turns, type of wire, and other variables. Some years ago each one of these coils was random-wound individually, which of course was a rather slow process, and subject to a number of variables that were difficult to control. An automatic machine was later developed by Western engineers which permitted the winding of eight of these coils in a stick form. Two of these machines are assigned to an operator, as shown in Figure 6. The winding making up these coils consists of thousands of turns and many layers of copper wire varying in size from 20 to 40 gauge. Each layer of winding is separated from the layer beneath by a sheet of cellulose acetate which is slipped in between each layer automatically without retarding the winding operation. When these sticks have been wound with the proper number of turns to meet a given resistance and inductance value, they are cut into

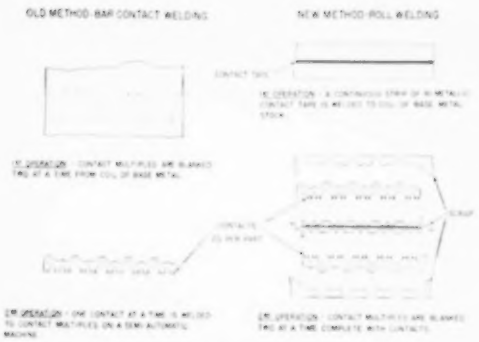


Figure 7—**Welding Contacts to Crossbar Switch Multiples**

spool lengths and each end of the coil is later closed in to completely seal the coil. We have currently in our production some 40,000,000 coils of this type, and the new method of producing the coil resulted in a reduction in manufacturing cost of over 40%. Here again, however, results of this development were two-fold in that the cost was not only greatly reduced, but also the quality of the coil was improved. You can appreciate that with the uniform winding that resulted, and having each layer insulated from the other, improved electrical characteristics were bound to follow. The number of short circuited turns, open coils, or grounds was greatly reduced. A maximum and a minimum resistance value must be satisfied by each coil, and the average number of outside-of-limit coils per 1,000 tests for resistance dropped from 9.4 encountered with the individually-wound coil to 3.6 with the stick-wound coil. In addition to that, due to the fact that the coil is completely sealed, it is much less subject to moisture absorption, and therefore is a more stable coil with respect to all of its electrical characteristics.

3. Welding Precious Metal Bar Contacts

A componet part of one of the switches used in the telephone exchange is made up of a strip of metal to which is welded 20 precious metal bar contacts, as shown by the left view in Figure 7. Currently 157,000,000 of these contacts are welded annually. These contacts were formerly welded one at a time by a semi-automatic machine which we had developed. While this was a satisfactory method, and used for several years, it did not lend itself to the speed that was needed to meet a large increase in production without incurring a large expenditure for additional machines. A new method was then devised which welded a continuous tape of precious metal to a continuous length of spring stock, as shown by the right view in Figure 7. Out of this stock the contact multiples are blanked two at a time with the contacts in place. The first step in this process is shown in Figure 8. The wire tape and the spring stock are fed between two rotating electrodes, and the two are joined together by a continuous weld. A close-up is shown in Figure 9. This combination of spring stock and contact tape is then passed through a punch press, as shown in Figure 10, where the springs are blanked with the welded contacts in place, as previously men-

Figure 8—**Machine for Continuous Welding of Wire Tape to Spring Stock**

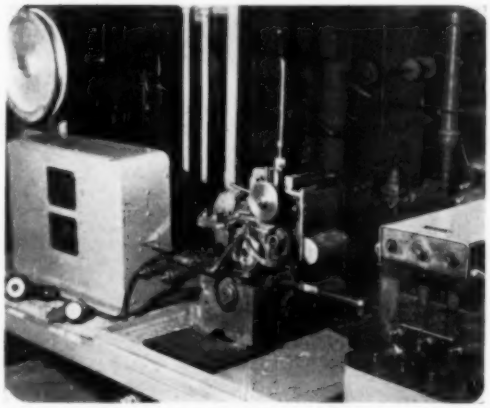


Figure 9—**Close-Up of Continuous Welding Operation**

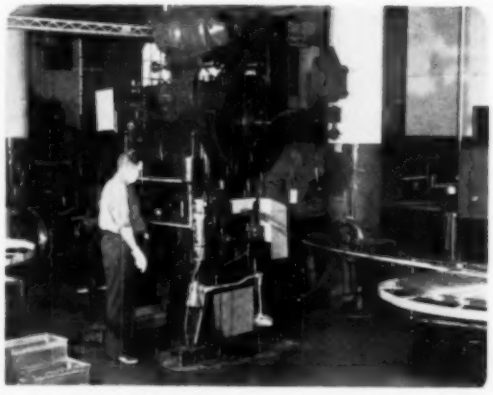


Figure 10—**Blanking Operation of Welded Wire Tape and Spring Stock**

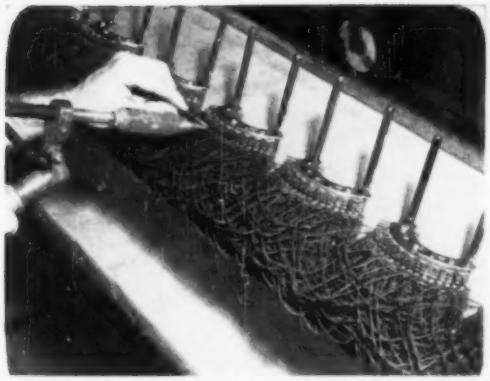


Figure 12—**Conventional Method of Soldering Wires to Terminals of a Multiple Bank**

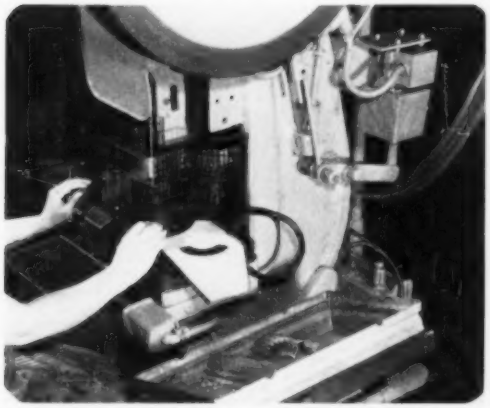


Figure 13—**First Step in Assembly under the New Solderless Process for Joining Wires to Terminals in a Multiple Bank**

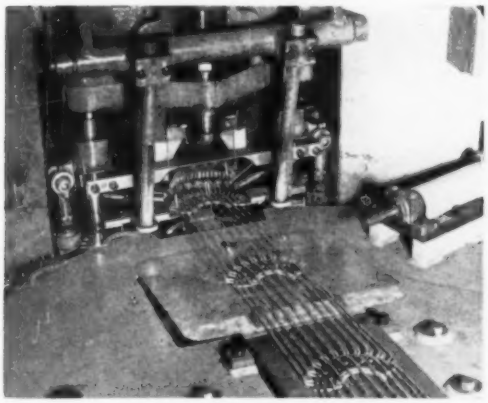


Figure 14—**A Subsequent Assembly Operation under the New Solderless Process**

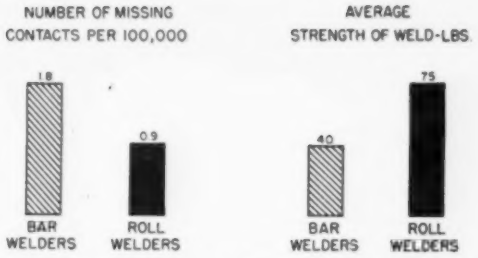


Figure 11—**Improvement in Quality of Welded Contacts when Roll Welders are Used**

tioned. This development resulted in a 25% reduction in the manufacturing cost of this part. While this result was very gratifying in the interest of lowering costs, along with it came a very marked improvement in the quality of the product, as shown in Figure 11. The strength of the weld, or the force required to break the joint between the contact bar and the spring was increased from an average of 40 pounds to an average of 75 pounds, an increase of 87%. This improvement was further reflected in the number of missing contacts encountered on the final product being decreased from 1.8 to .9 per 100,000 contacts, a 50% improvement in this respect. While one missing contact in 100,000 chances may not appear significant, it must be remembered that a missing contact is a potential failure of a telephone connection, and we consider the above improvement of high importance.

4. Soldering Wires to the Terminals of a Multiple Bank

Figure 12 shows the conventional method of soldering wires to the terminals of a multiple bank which is used in certain types of telephone exchanges. The assembled bank is in position in front of the operator, and the bank multiple wire on which the insulation has been broken at equally spaced intervals to coincide with spacing of the terminals, is looped around a terminal at these points, and then soldered one by one, layer by layer, until all the connections are made. 274,000,000 connections of this type must be made annually, based on the present production rate.

A drastic change has been developed in this process effecting a change in every part of this equipment. Space does not permit including many of the details. Figure 13 shows the first step in the assembly operation. The terminals have been blanked with one end formed in a "U" shaped section to receive the wire in a later operation. On the inside of this "U" section, two sharp prongs have been sheared. These terminals are blanked with enough stock connecting them to form the ribbon seen at the right. This ribbon is then fed through a punch press where the terminals are separated, and ten are attached to each of the two insulators simultaneously. This assembly is then transferred to a tool in another press, shown in Figure 14, and so positioned that a textile-insulated, stranded wire is placed in the "U" section of each of the twenty terminals directly over the projecting prongs mentioned before. When the press is operated, twenty plungers come down and clinch a "U" band of a terminal tightly around each of the twenty wires at the same time. This in turn forces the

Figure 15—**Sectional View of Contact under the New Solderless Process**

prongs through the insulation on the wire and into the strands of the wire, thus forming a reliable mechanical and electrical connection between the terminal and the wire. This operation is automatically repeated at definite intervals as the wires are drawn through the press, forming a ladder-like structure as shown. The enlarged sectional view (Figure 15) illustrates the type of connection made. This ladder structure is then piled in ten tiers, as shown in Figure 16, to form the completed bank with the wires already attached to the terminals, thus eliminating all of the soldering operations. Manufacturing costs were reduced by 30%, and in addition the following quality improvements were effected:

1. Stranded wire replaced solid wire, thereby greatly reducing wire breakage.
2. All solder splashes, which are always a source of trouble, on a congested wiring job, were completely eliminated.
3. All chances of reversed wires were prevented by mechanical means.
4. The clinched tip connection proved to be a more reliable connection than the former soldered joint.

5. Making Wire Connections for a Telephone Relay

Let me conclude by citing one more instance which differs somewhat from the preceding ones, in that the primary goal of the engineer in this case was to find a way to improve a long established practice of connecting wires to terminals to eliminate some inherent difficulties that affected the quality of the product. This was accomplished very effectively by means of a pistol-like tool which you may recognize from Figure 17 as the illustration you have seen in a widely exhibited Western Electric Company advertisement. Figure 18 shows a typical telephone relay to which is attached a number of wire connections. Until very recently the practice followed was to thread that part of the wire from which the insulation had been removed through the hole in the end of the terminal and to bend the wire back on the terminal. The next step was to join the wire to the terminal by a soldering operation. The third operation was that of clipping off the loose end of the wire. This procedure gives rise to three potential sources of difficulty. First, the wire is not anchored securely to the spring before the soldering operation, and this condition may cause a poor soldered connection; second, the wire is bent back on itself after being threaded through the hole in the terminal, and is subject to breakage in sub-

Figure 16—**Forming the Completed Bank with Wires Already Attached to Terminals**

Figure 17—**Part of a Recent Western Electric Ad**

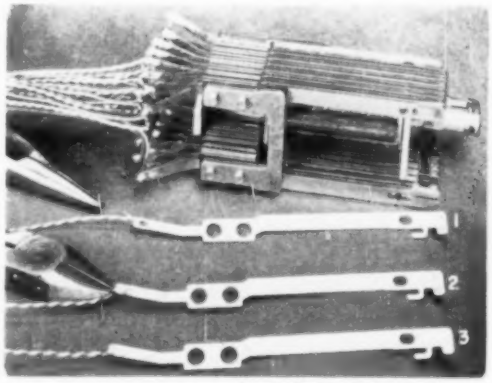


Figure 18—**Previous Three-Step Method for Connecting Wires to Terminals in a Telephone Relay**

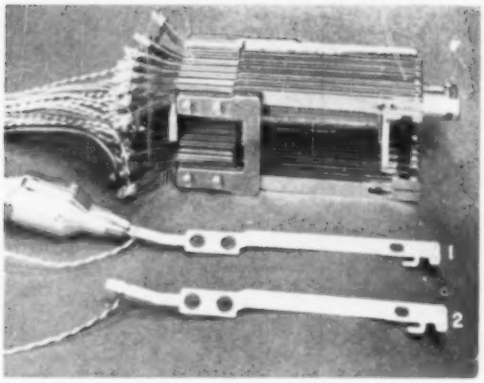


Figure 19—**Improved Two-Step Method Using the New Tool**

Figure 20—**The New Tool in Operation**

Figure 21—**A Wiring Job Completed by Use of the New Tool**

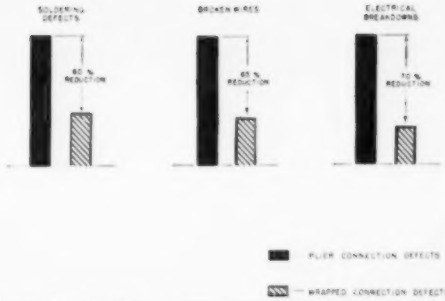


Figure 22—**Quality Improvement Achieved with Mechanically Wrapped Connections**

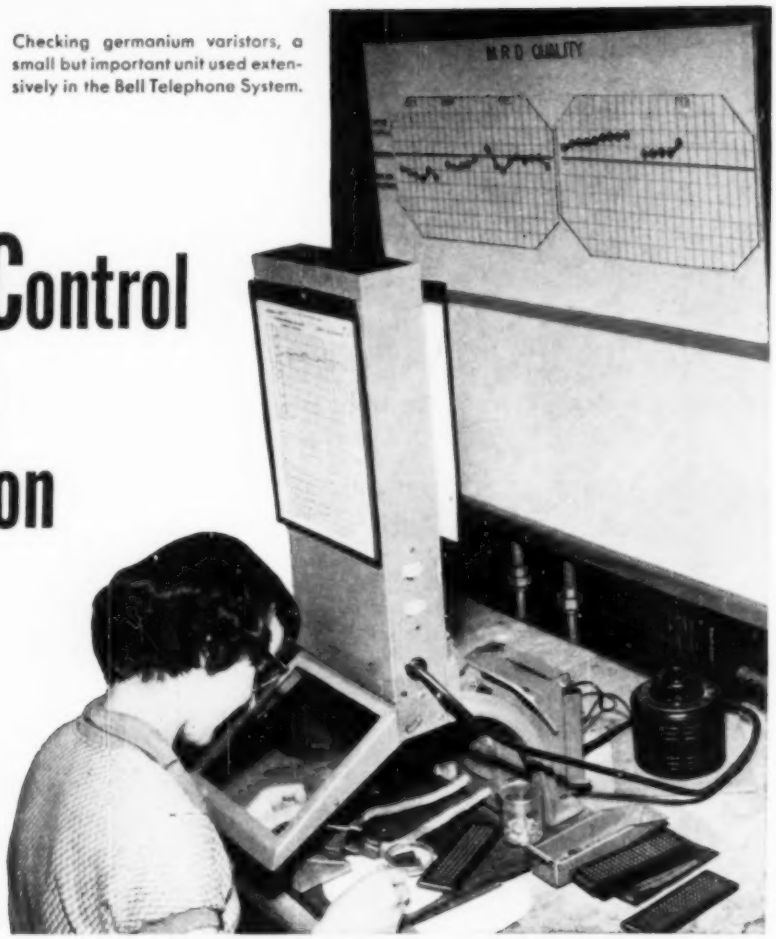
sequent handling; and third, when the loose end of the wire is clipped off after soldering it has an excellent chance of falling down in the maze of wires and terminals on wired equipment frames, and causing a short or grounded connection. This is often very difficult to detect, and frequently continues to lodge in a troublesome position even after the frame has been subjected to a blast of air in the final cleaning operation. This difficulty was overcome by the tool previously mentioned, and from Figure 19 it can be seen that by means of this tool the wire is wrapped snugly around the terminal without a loose end projecting. This forms a secure connection between the spring terminal and the wire and creates a much better condition for a good soldered connection. This view of the operation has been over simplified to show more clearly how the tool operates. The real field of operation, however, is much more challenging, as may be seen in the before and after views, Figures 20 and 21. Note from Figure 22 that the use of the improved method has reduced the number of defective soldering joints by 60%, has reduced the number of broken wires encountered by 65%, and the number of electrical breakdowns, principally caused by wire clippings, 70%. In addition to this improvement in quality which the engineer started out to get, a substantial reduction of some 25% in the manufacturing cost of these operations was effected.

CONCLUSION

These few cases from the experience of the Western Electric Company I hope have served to support the view that low product costs and high product quality are not conflicting, but rather supporting factors of quality in its broadest sense. You will have noted that in the cases I have cited the customer and the manufacturer have both benefited very materially—the customer through increased usefulness of the product and the manufacturer through significant improvements in the uniformity of product, which means fewer rejects. These latter improvements in the uniformity of product quality have provided increased opportunities for the application of statistical quality control techniques with their accompanying economies. As the engineer, through the advancements in the arts of manufacture that are being developed constantly, more effectively engineers for lower costs and higher quality, to the same degree I am sure will more effective quality control procedures be developed and their applications extended. This goal I commend to the American Society for Quality Control, and wish you great success in attaining it.

Checking germanium varistors, a small but important unit used extensively in the Bell Telephone System.

Quality Control in Action



In the picture you see evidence that SQC is no "ivory tower" theory with Western Electric. It gets right down to day-by-day practice in our plants. We've found that when employees become quality and cost conscious, quality of product is high, defects and scrap losses are low. • That's good business for us. It's good for employees, because of an increase in their acceptable production. It's good for telephone users, because it helps give them the best telephone service on earth at low cost.

Western Electric

A UNIT OF THE BELL SYSTEM SINCE 1882

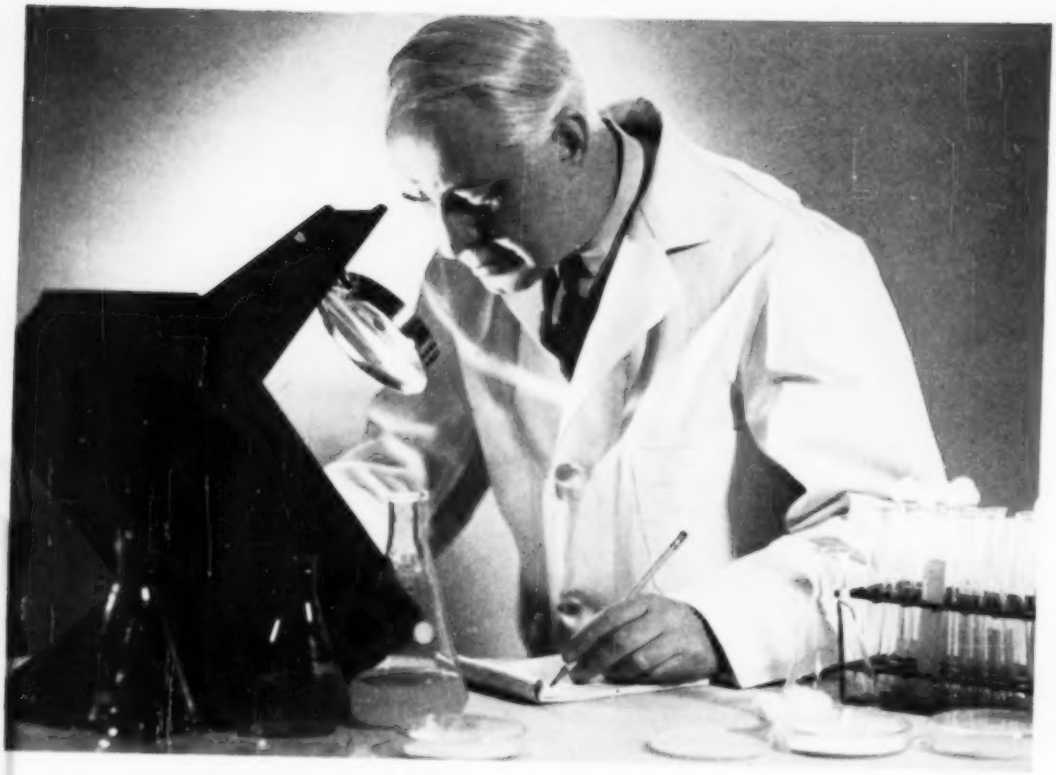
REMEMBER WHEN "get out and get under" was not only a popular song, but a necessary nuisance? Thompson Products was born with the automobile 50 years ago, soon helped make the tool box obsolete.

What happened TO THE TOOL BOX ON THE RUNNING BOARD?

Thompson recognized the needs of the industry, turned out better valves, pistons, tie rods. Where improvement was needed, Thompson went to work. Soon the automotive—and then the aircraft industry—learned to count on Thompson.

Industry as a whole is learning what automobile and airplane builders have known for 50 years—that you can *always count on Thompson.* Thompson Products, Inc., General Offices, Cleveland.

You can count on Thompson



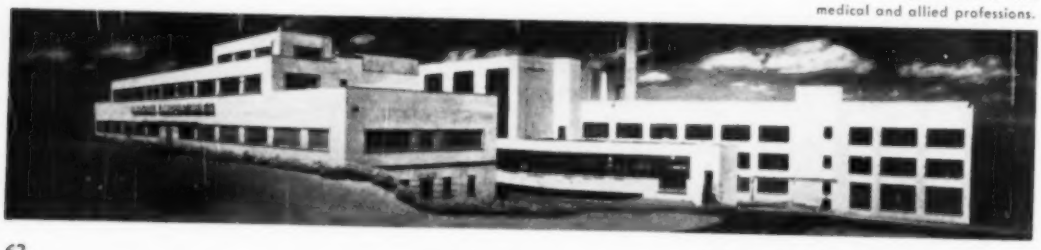
In the pharmaceutical industry **LIVES** *depend on quality control*

In no other field is it quite so true that too much of a good thing . . . or too little . . . can be disastrous. With few exceptions, a drug's potential for good is directly matched by its potential for harm in the event of misuse or error.

In the manufacture of antibiotics and specialized pharmaceuticals for alleviating human illness, Bristol Laboratories enforces a rigid system of checks and counter-checks at every step . . . from the receiving platform to the shipping room . . . to assure unvarying consonance of potency and composition with label specifications on each of its many products. There can be no compromise – a human life may depend on it.

Bristol
LABORATORIES INC.
SYRACUSE NEW YORK

Producers of antibiotics and pharmaceutical specialties for the medical and allied professions.



Building Morale through Quality Control

E. H. ROBINSON
Director of Quality Control, Johnson & Johnson, Chicago, Illinois

THE building of morale within an organization can be done at many points. In a paper presented in the January, 1950, issue of *Industrial Quality Control*, the author pointed out how Quality Control can, through working closely and cooperatively with the Purchasing, Cost, Production Planning, Development, Sales, and Shipping Departments, improve the efficiency of their respective operations and thereby help to build their morale.

Let us now look at the most important relationship of all—the one with the Manufacturing Department—and analyze some ways in which quality control can help build operator morale.

The first brick in this building program should be laid when the employee is hired, and before he has started on his new job. Quality Control can assist during this indoctrination by pointing out to the new employee the vital need for quality production on his job. This very job was made possible, it should be emphasized, only because of sustained sales, which in turn are possible only because of the maintenance of high quality level. The employee should be made to realize, therefore, that his job is his personal stake in the company's quality reputation, that the customer pays his salary, and that he must therefore help the customer to obtain a uniform product of satisfactory quality. This fact cannot be impressed upon him too deeply, for if he doesn't have a clear-cut goal and want strongly enough to reach that goal, he is not likely to learn or develop adequately.

Quality Control can, through emphasizing the need for quality consciousness, make the new employee feel that he is not regarded just as a little cog on a big wheel but that his job is unique and important to the success of the company. He will be made to realize that quality cannot be inspected into a product; it must be built into it, and he is the only one who can do the building. The mere fact that he was hired demonstrates our respect for his potentialities, and thus challenged, it is basic that he is stimulated to a high level of job performance.

Through Quality Control helping the employee see the importance of doing a quality job, we give him a strong incentive to learn and to obtain satisfaction of the universal human ur to be of some significance. Failure on our part to thus properly indoctrinate the new employee will give him no tie of interest in the objectives of management.

When the new man starts on his job, the first thing we must do, of course, is to show him what must be done. As this is going on, however, Quality Control can, working through his foreman, point out the importance of each step in determining the quality of the finished product. The need for definite standards close at hand and the desirability of consulting them frequently can be impressed upon him. Quality Control can play a major role at this point in teaching the employee the meaning of variability and the subsequent need for tolerances. Together with the production supervisor and the cost man, Quality Control can demonstrate the effect of deviations on production costs and once again emphasize the employee's responsibility to the customer.

The employee thus begins to learn that cost consciousness and quality consciousness are synonymous and not antagonistic. He is alerted to the effective use of materials and equipment, to the prevention of waste, and to the improvement of work methods. He will make mistakes, of course, but we must build his confidence by showing that we expect people to make mistakes while they are learning. We must soft-pedal criticism and try to convince him that we are sure he will succeed. To insure this and guard against breaking his spirit, we should first give him a series of assignments we know he will be able to do well.

When the employee begins to make progress, we must be generous in giving praise or recognition, and here again Quality Control can be of great help through its progress reports. Praise is too often reserved for outstanding accomplishment, when actually it is needed most by the employee who hasn't gotten very far yet.

Praise for progress is one of the strongest incentives for further improvement. When a man has achieved some little success, particularly if it is recognized, something happens inside him that increases the probability that he will become even more successful. When an employee discovers after a short time on a new assignment that he is progressing well, he gains increased confidence in his ability to do the job. Like all of us, he becomes interested in things he finds he can do well, and thus improves his own standards of performance.

Even if the success of a project has been due largely to Quality Control rather than to an employee's individual effort, morale can be

greatly strengthened if credit for the performance is given to the spotlighted employee, and if the praise is lavish. Under such conditions, the employee will be encouraged to suggest ways and means of handling and correcting poor quality situations, and he will be eager to assist in the analysis of problems.

On the other hand, when a man is doing unsatisfactory work, Quality Control can earn his gratitude and future friendship by patiently studying his operation and making suggestions for correction. At the same time, advantage can be taken of this opportunity to develop the employee's ability to think out his problems and to reach conclusions independently. By emphasizing what is important and *why* it is important, Quality Control can help him learn more quickly and improve his performance. Instead of being suspicious of suggestion and fearful that it represents criticism, he learns to recognize it as an effort on the part of Quality Control to build him up. He learns that the main interest of Quality Control is helping him to improve, not in catching him in a mistake or proving that he is wrong. Show him that you have confidence in him, for if he senses a lack of confidence, he will retaliate with an attitude of non-cooperation.

While it is certainly true that kindness, friendliness, and sympathy pay big dividends, it is important to avoid the error of tolerating inferior work to build up Quality Control as a "good fellow". The employee should be protected against undeserved adverse criticism, but he should not be shielded from the results of major neglect. Where it is deserved, Quality Control should be firm, for employees not only respect but desire discipline which is certain and fair.

One cannot be too careful, however, about refraining from rendering judgment before a complete hearing. The flow of talk from the employee should be primed by asking questions rather than by making accusations. Listening should be patient and without display of anger or irritation. It must always be kept in mind that just as "Quality is remembered long after the price is forgotten" so also "A disparaging word is remembered long after the praise is forgotten."

In building employee morale, it is fundamental not to hold the employee responsibile for quality production if we are not supplying him with satisfactory raw materials. Most people prefer to do good work, but they will continue to do so only if they feel their supervisors are interested. Failure on the part of supervision to supply satisfactory raw materials does not demonstrate that interest, and will eventually result in a low quality level.

Sometimes, of course, raw materials cannot be improved because of conditions beyond management's control. More often, progress in this direction is slow until the vendors understand the problems involved. But if the employee knows that management is working closely with vendors, and that sincere effort is being made to improve his materials, his morale is strengthened and he is encouraged to do the best he can until success is attained.

The program of improving vendor quality is not an easy one. Key people in both the vendor's and manufacturer's organizations must exchange visits so that each will understand the problems and needs of the other. Very often, it is necessary to familiarize the vendor with quality control techniques which he may apply in the manufacture of his material. Specifications must be clear, compleie, and understood by all. To insure a common basis for determining quality level, a check list should be prepared by collaborative action and used regularly by both parties. Above all, incoming inspection should be made immediately on receipt of the raw material by Quality Control, and only that which is satisfactory should be released.

In some companies, the training of vendors is so advanced that vendors submit control charts or frequency distributions with each shipment. These vendors are then evaluated at regular intervals and informed of their comparative ratings. In fact, a number of companies have already reached a point in this training where they soon expect to eliminate incoming inspection almost entirely.

With satisfactory raw materials reaching the employee, it is reasonable to hold him directly responsible for the quality of finished product. Such an arrangement has many advantages, for in many companies, unfortunately, Quality Control personnel is too limited to assume inspection responsibility. Further, immediate and rapid inspection is necessary if rejects are to be kept at a minimum. If the operator is fully informed as to standards, if he really understands them and is provided with equipment so that he himself can set aside any sub-standard work done by him, he is not likely to produce many rejects. If the fault is his own, he will try to correct it or get help. If the fault is with his machine or previous operations, he will report it. Conditions needing attention, therefore, will come to light and be reported before much scrap is made.

Aside from the economic gain which can be realized by people doing their own inspection work, participation in the control of quality stimulates employee morale, for then the operator develops the feeling of being a part of, rather than apart from, the company management. He loses the feeling that he is blamed for things beyond his control, because he can report a condition as soon as he finds it adversely affecting his product. He begins to contribute ideas about his job, a job about which he knows more than anyone in the plant.

Participation by the operator in the constant check on and control of quality will not eliminate all independent inspection. Some inspection is still necessary to determine the extent to which defective material is being allowed to flow into finished production. Operators who fail to control the quality of their work will have to be identified and helped. If a piece is rejected, the reason should be determined and made clear, and the supervisor should instruct the operator in the proper methods. If the defect was caused by a faulty machine, it should be repaired immediately. If all this fails, and the employee cannot or will not be helped, he must be eliminated.

Quality Control then becomes a secondary inspection group which can act in an advisory capacity when there is doubt as to acceptability. Also, by keeping the operator advised as to his quality level and the supervisor advised as to the quality performance of each worker, it will be constantly improving existing quality standards.

Not only must the employee know what he is supposed to do and be given the proper tools with which to do it, but he must know how he is getting along. These conditions must all be present before he can be held responsible for quality. To

build his morale, he must know whether his efforts are resulting in reduced waste, increased production, greater uniformity, or lower cost. It is normal for a man to want to work for a company that can increase its earnings, particularly when he knows he is contributing. It gives him a feeling of job satisfaction and a sense of economic security.

One of the most profitable devices which Quality Control has been able to develop for building morale has been the decentralization of Quality Control groups by manufacturing mill. Using this technique in our own company, each mill has its own Quality Control group with its personnel and equipment located physically within the boundaries of that mill's operation. The group is headed by a supervisor who, while he is technically a member of the Quality Control Department and as such responsible to the Director of Quality Control, is for all practical purposes a member of that mill superintendent's staff. He attends all mill staff meetings, is called on for reports, contributes to general discussions, and occasionally conducts the staff meeting when quality is the main topic.

Operating in this way, the Quality Control group knows, appreciates the need for, and supports production plans and schedules. A feeling of belonging is developed, and the mill learns that Quality Control is a service function, not a police function. By creating an atmosphere of group solidarity, Quality Control can effectively direct group energy into channels of constructive achievement, and can break down the tendency of operators to band together for passive resistance.

Since the foreman's day-to-day activities require his full time and he cannot spare any to perform long-range jobs, he welcomes an on-the-spot group which can develop facts on which he can base decisions. This group can collect, analyze, and present to him any evidence suggesting changes in production methods to meet quality standards more efficiently. The close proximity of this group enables his operators to inform it immediately of a sub-standard operation, and the exclusiveness of the mill Quality Control group enables it to throw the full weight of its resources into the solution of the problem.

With the physical equipment of the decentralized Quality Control

MEASURE IN MICROINCHES RMS

Production Efficiency *increased*

because BELL Aircraft CORPORATION **uses the PROFILOMETER**

Bell Aircraft Corporation of Buffalo, New York, in production of Guided Missiles, Supersonic Aircraft, Rocket Motors and Airborne Electronic Equipment finds the Profilometer has increased their production efficiency. At Bell the development of guided missiles is of great magnitude. While the work in this field is of a restricted nature, it can be reported that the Profilometer has become of standard use in production techniques.

A specific example is Bell Aircraft production of high precision valves. Extreme surface accuracy in machining these high precision valves is of prime importance. For these surface measurements Bell turned to the Profilometer for the necessary answers. The I.D. surface of these valves, shown being measured above, must produce a maximum reading of four microinches! Bell found that the Profilometer would give these readings fast and accurately thus saving valuable machining time in production.

Extremely accurate surface measurement is essential to Bell Aircraft today in research and production. The Profilometer is supplying this information. This is just another example of the use of the Profilometer as an important *shop instrument.*

To learn how the Profilometer can help cut costs in your production, write today for these free bulletins.

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unit located close to the operator's machine, he is encouraged to learn its use and to assume greater responsibility for the control of his quality. In taking over this function, he is made to realize that time is thus freed for the solution of serious quality problems in his own mill. A pride in group progress is developed within the mill, and discipline is maintained by using pressure on non-conforming members.

The decentralization of the Quality Control group is carried to the point where any major change in policy or personnel is first reviewed with the mill superintendents affected. When group supervisors are shifted or promoted, when replacements are being considered, when established tests are abandoned and new ones adopted, and in many other situations, the plan is described to the mill superintendent and his approval first obtained. He is in agreement before the change is made.

It is often argued that Quality Control decentralization can result in the breakdown of quality standards, through the Quality Control group becoming integrated with the mill staff and losing its objectivity. This is certainly a logical argument, and will undoubtedly occur if the Quality Control Department is poorly organized and does not answer to a management executive. If, however, the organization is strong and receives the active support of such an executive, the many proved advantages of decentralization far outweigh the theoretical disadvantages.

There are many ways in which Quality Control can amplify these basic management concepts to build morale.

The use of large, colorful posters, displayed frequently at strategic points throughout the plant, can emphasize the need for quality production. These posters are particularly effective if they combine a simple background picture with a short, hard-hitting message. In some companies interest is increased by awarding prizes to employees selected at random if they can describe the poster on display.

The use of a quality award for outstanding production during the preceding month has been an effective tool. This award may take the form of a trophy, a bulletin, or a banner, and may be as simple or as elaborate as the employees wish. Since it is difficult to be completely objective in making such an award, it is often considered wiser to make the award to *every* department which has done a good quality job instead of singling out one group. In doing this, all excellent performances are recognized and further, those not receiving awards are in a smaller, more conspicuous group.

At Johnson & Johnson each department which has done an outstanding quality job during the previous month, as reported in the monthly Quality Award reports of the Quality Control Group Supervisors, is recognized. A lucite banner, in the form of an unrolled scroll four feet long and three feet wide, is hung in the central aisle leading from the employees lobby into the plant. This banner is inscribed with the legend "THESE DEPARTMENTS DID AN OUTSTANDING JOB OF MAINTAINING OUR QUALITY REPUTATION" and shows the names of the Quality Award winners for the past month. Small red crosses are hung after each department name on the banner to indicate the number of times during the current year the department has been recognized.

At the beginning of each month, the Quality Award winners for the previous month are named by the Quality Control Department and announced at the monthly meeting of the Labor-Management Committee. Letters commending the departments are then distributed to their representatives. Immediately following the meeting, the letters are posted on department bulletin boards and the names of the winners are hung on the scroll with the appropriate number of red crosses. These names and red crosses remain on the scroll until the winners for the new month's activity are announced.

Sometimes, a department is not eligible for the quality award but has done an outstanding job in raising its quality level. In such cases, a letter of commendation is often written by Quality Control so that the letter may be posted and serve to stimulate the department em-

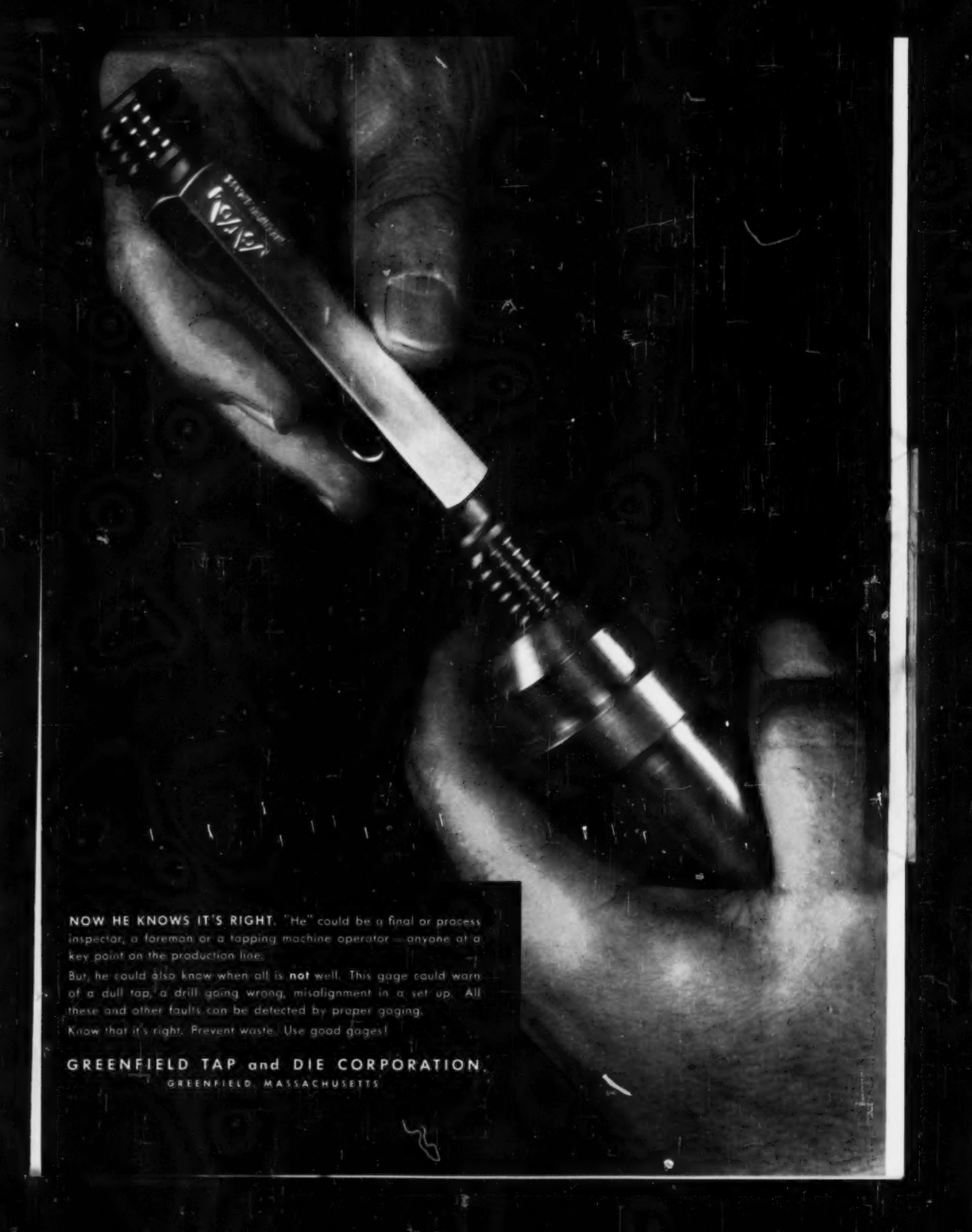
CONGRATULATIONS

AMERICAN SOCIETY FOR QUALITY CONTROL

THE DUMORE COMPANY

RACINE, WISCONSIN

Precision Builders of Electrical Tools and Motors for Almost 40 Years



NOW HE KNOWS IT'S RIGHT. "He" could be a final or process inspector, a foreman or a tapping machine operator — anyone at a key point on the production line.

But, he could also know when all is **not** well. This gage could warn of a dull tap, a drill going wrong, misalignment in a set up. All these and other faults can be detected by proper gaging.

Know that it's right. Prevent waste. Use good gages!

GREENFIELD TAP and DIE CORPORATION.

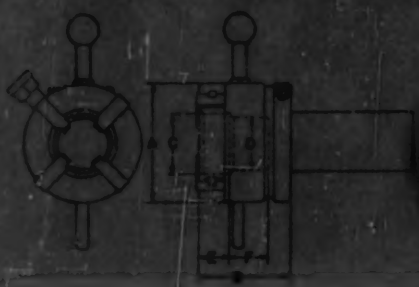
GREENFIELD, MASSACHUSETTS

GEO MET RIC **C**

self-opening die head

for light duty threading on hand operated machines

Style C



SPECIFICATIONS STYLE C WITHOUT LATERAL FLOAT ... L-OFF TRIP

Style and §Size Inches	Construction Number	CAPACITY				Code Word	A	B	C	D			SHANKS					
		Straight Threads			Standard Pipe Threads								Standard		Also Available			
															‡Max.		△Min.	
		Diam. Inches	Lgth.	Coarsest Pitch									Dia.	Lgth.	Dia.	Lgth.	Dia.	Lgth.
C-1¼	12678-K	⅛" to 1¼"	2"	8	⅛"– ¼"	Cameo	3½"	3"	1⅝"	1⅝"	1⅛"	1⅝"	1¼"	3¼"	1½"	3¼"	1"	1½"
C-1¾	A6393-D	¼" to 1¾"	2"	8	½"–1¼"	Conter	4½"	3½"	2⅛"	1⅞"	1⅛"	1⅞"	1¾"	4"	2⅛"	4"	1⅛"	2"
C-2⅛	A5167-J	1¼" to 2¼"	2¼"	8	1" –1½"	Canvas	4⅛"	3½"	2⅛"	2⅛"	1⅛"	1⅛"	2"	4¼"	2⅛"	4¼"	1¼"	2"
C-2½	20504-F	1½" to 2½"	2"	8	1¼"–2"	Carte	5¼"	3½"	2⅛"	2⅛"	1⅛"	1⅛"	2¼"	4½"	2⅛"	4½"	1¼"	2"
†C-2½	12744-D	1¼" to 2½"	3⅛"	7	1" –2"	Carmine	5¼"	4⅛"	2⅛"	2⅛"	1½"	2⅛"	2¼"	4¾"	3"	4¾"	1½"	2¼"
C-3	30123-H	1½" to 3"	2½"	8	1¼"–2"	Catch	5¼"	3½"	3⅛"	3⅛"	1⅛"	1⅛"	2¼"	4¼"	3⅛"	4¼"	1½"	2¼"
†C-3⅛	93271-R	2⅛" to 3⅛"	2¼"	8	2"	Cement	6½"	3⅛"	4⅛"	3⅛"	1¼"	2⅛"	2½"	5"	4⅛"	5"	1¼"	2½"
†C-4¼	49270-C	2⅛" to 4¼"	3½"	7	***2½"–4"	Certain	8¼"	5¼"	5⅛"	4⅛"	1⅜"	2⅛"	2¼"	5½"	5"	5½"	2"	3"
†C-6	28831-E	3½" to 6"	3¼"	7	***3" –5"	Chauk	11"	5½"	6⅛"	6⅛"	1¼"	3"	3"	5¼"	5½"	5¼"	2⅛"	3"

§Other sizes can be furnished where required. Price quoted on specific inquiries.
†These Die Heads are fitted with Roughing and Finishing Attachment.
*Length that can be cut when shank is solid.
***Projection Chasers required for pipe sizes within listed capacities.

‡Maximum shank without bushing.
△Minimum recommended size.

GEOMETRIC TOOL COMPANY DIVISION
Greenfield Tap and Die Corporation
NEW HAVEN 15, CONNECTICUT

ployees to even greater improvement.

Audit Reports are often used to describe a department's operation, and to represent the summary of results obtained by periodically examing finished products selected at random from the Shipping Stores. This is often an effective device for pointing out operators who need special attention.

A number of companies have had a good deal of success using Report Cards. This technique must be carefully handled, or it may boomerang to destroy rather than build morale. To be effective, the report card should be regarded as a personal matter, and should be reviewed privately with the employee. His score for the rated period should be compared with the group so that he knows his comparative position, but he should never be told who is below and who above him. If his performance is better than the average of the group, he should be complimented and encouraged to do even better; if he is below average, an attempt should be made to determine what is wrong and he should be given every possible assistance.

Employees should be given every opportunity to study quality control procedures. Training sessions should be organized, and the Personnel or Training Department should work with the Quality Control Department to teach the simple, fundamental principles of variation, tolerances, frequency distribution, and probability. Naturally, the instruction must be pegged for the level of the students. If too much statistics is introduced, and complicated formulas are developed and studied, the employee will not only lose interest but will actually fight the application to his operation. On the other hand, if he is properly indoctrinated, his interest is aroused and he is anxious to see what it can do for him.

These represent a few of the devices being used by Quality Control today to build employee morale and improve production quality. As the science of quality control grows and as we become as proficient in human relations as we are in statistical techniques, new and even more effective devices will be developed. We have made some progress, but much yet remains to be done.

A Complete Line of Dial Indicators and Dial Gauges— for EVERY DIMENSIONAL PROBLEM

● For more than 50 years, B. C. Ames Co. has produced the highest quality micrometer dial indicators and micrometer dial gauges. That's as true today as ever—and it's one reason why Ames' Products are in such great demand — why you have to wait just a bit longer than you'd like for your order to be delivered.

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Represented are some of the various micrometer dial indicators and micrometer dial gauges built by Ames. They can be had to ASTM and TAPPI standards — or if you have a special measuring or quality control problem, let our engineering department assist you. We've made gauges for measuring such diverse things as primer charges and potato chips.

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An old-fashioned dollar's worth! Compare the fares!

Basic one-way fares on United have gone up only about 4½% since 1941—much less than first-class surface fares! Here are some examples of how they now compare!

	First-class rail plus lower berth	First-class DC-6 Mainliner	SAVING BY FLYING UNITED
CHICAGO-NEW YORK	$49.79	$44.10	$5.69
PHILADELPHIA-DETROIT	$35.51	$26.85	$8.66
NEW YORK-SAN FRANCISCO	$144.45	$157.85	No tips aloft, and United's fares include meals so you still save.
LOS ANGELES-SEATTLE	$59.41	$63.55	

Tax not included in above fares.

Not only are United fares almost as low as 1941, in contrast to most products and services, but the quality and speed of Mainliner transportation have greatly improved. Today you enjoy 300-mile-an-hour speed in 4-engine DC-6 Mainliners, with pressurized cabins for your comfort at high altitudes. You benefit from all-season schedule dependability. And your comfort and enjoyment are further enhanced by superior food and service. You still get an old-fashioned dollar's worth, *and then some!* Every dollar you spend on United Air Lines buys more than ever before!

UNITED AIR LINES

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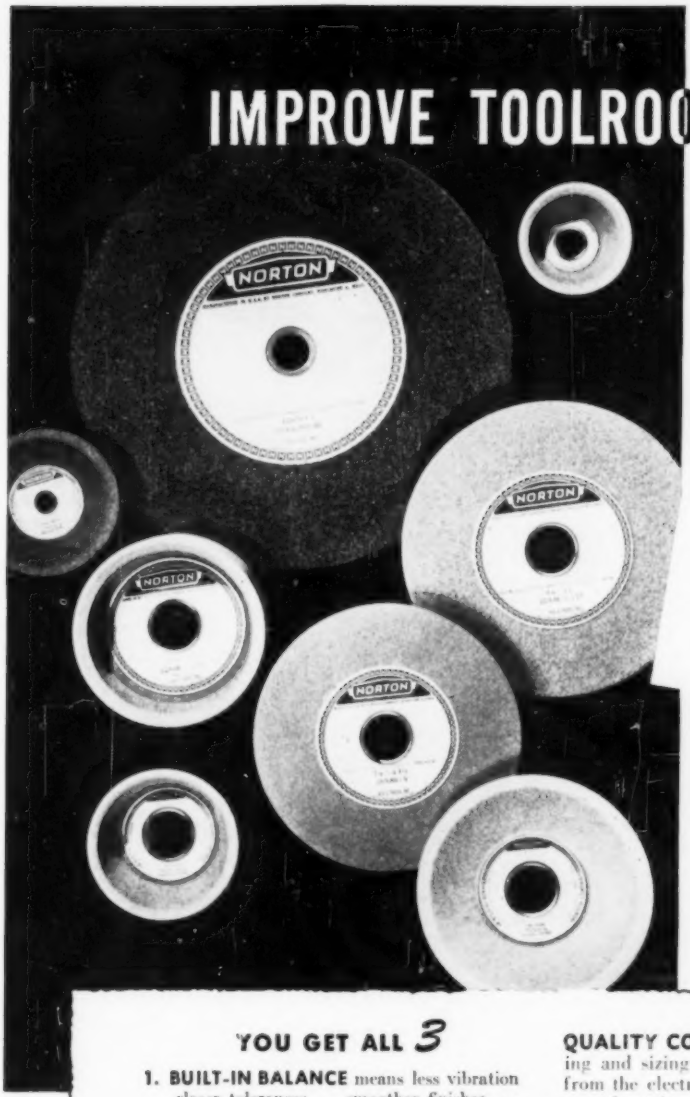
IMPROVE TOOLROOM GRINDING



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NORTON *NEW-PROCESS* GRINDING WHEELS

Truly uniform within each wheel and from wheel to wheel

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1. BUILT-IN BALANCE means less vibration . . . closer tolerances . . . smoother finishes . . . no chatter marks. And this inherent balance stays for the life of each wheel.

2. MORE UNIFORM STRUCTURE means slower and more even wear . . . fewer machine adjustments . . . sharp reductions in tool spoilage . . . assurance that all identically marked wheels will perform identically.

3. FASTER, SMOOTHER, MORE EFFICIENT CUTTING ACTION with the right Norton Alundum* abrasive means deeper cuts in expensive, high-speed steel and cast alloy tools without drawing their temper . . . less frequent dressings . . . big savings in time and toolroom grinding costs.

QUALITY CONTROL—From the screening and sizing of the abrasive as it comes from the electric furnace plant to the final manufacturing process in the new Norton five-acre building, quality control plays an important part in giving Norton New-Process Wheels their exceptional uniformity.

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Making better products to make other products better

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All of the officers of each Section are listed in the Year Book. The National Directors and presiding officers only are shown here. They are listed alphabetically by Section within the Region. The National Director is shown first.

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ANNOUNCING THE

Sixth Annual Convention
American Society for Quality Control

Onondaga County War Memorial Auditorium, Syracuse, New York

Thursday, Friday, Saturday—May 22, 23, 24, 1952

EVENTS OF INTEREST

Thursday, May 22, 1952

8:30 - 10:30 am REGISTRATION—West entrance, War Memorial Auditorium

9:00 am - 6:00 pm EXHIBITS

11:00 - 12:00 am OPENING ASSEMBLY—Main Auditorium

Dr. W. R. G. BAKER, *Vice-president and General Manager, Electronics Division, General Electric Company.*

12:15 pm LUNCHEON—Announcements—Auditorium

2:00 - 5:00 pm LADIES PROGRAM—A Tour of Local Manufacturing Establishments.

2:00 - 5:00 pm EDUCATIONAL SESSIONS

2:00 - 4:00 pm TECHNICAL SESSIONS

4:05 pm ANNUAL MEETING OF ASQC—Auditorium, 3rd Floor, North.

6:15 pm ANNUAL BANQUET—ASQC Program—Auditorium

9:30 - 11:30 pm COMMITTEE MEETINGS—Hotels

Editorial Board	Onondaga Hotel
Auditing Committee	Syracuse Hotel
Publicity Committee	Onondaga Hotel
Textile Technical Committee	Onondaga Hotel
Relations with Tech. Societies	Syracuse Hotel

Friday, May 23, 1952

8:00 - 10:00 am COMMITTEE MEETINGS—Hotels and Auditorium

Shewhart Medal Committee	Syracuse Hotel
Automotive Technical Committee	Onondaga Hotel
Chemical Technical Committee	Onondaga Hotel
General Committee Chairmen	Syracuse Hotel
Electronics Technical Committee	Onondaga Hotel

9:00 am - 6:00 pm EXHIBITS

9:00 - 12:00 am EDUCATIONAL SESSIONS

10:00 - 12:00 am TECHNICAL SESSIONS

12:15 pm LUNCHEON—Brig. Gen. Ralph H. Tate, U.S.A. Ret.—*President, Camillus Cutlery Company, Camillus, N. Y.* "THE MARCH OF COMMUNISM."

12:15 pm LADIES PROGRAM—Luncheon and "Technical Session" at Tubbert's.

3:00 - 5:00 pm EDUCATIONAL SESSIONS

3:00 - 5:00 pm TECHNICAL SESSIONS

5:00 - 7:00 pm ELECTRONICS TRADE MEETING—Auditorium. All those connected with the Electronics Field.

5:00 - 7:00 pm COMMITTEE MEETINGS—Auditorium

- Aircraft Technical Committee
- Convention Committee
- Education Committee
- Examining Committee
- Standards Committee

9:00 - 12:00 pm SOCIAL EVENING—Hotel Syracuse

Saturday, May 24, 1952

8:00 - 9:30 am COMMITTEE MEETINGS—Hotels

Brumbaugh Award Committee	Syracuse Hotel
Membership Committee	Onondaga Hotel
Program Committee	Onondaga Hotel
Section Representation	Syracuse Hotel
Technical Committee Chairmen	Onondaga Hotel

9:00 am - 5:00 pm EXHIBITS

9:00 - 12:00 am EDUCATIONAL SESSIONS

9:30 - 11:30 am TECHNICAL SESSIONS

Noon LUNCHEON—Mr. Hugo Weissbrodt, *Works Manager, Fort Wayne Works, International Harvester Company.* "QUALITY CONTROL, THE KEY TO IMPROVED EMPLOYEE RELATIONS."

2:00 pm BOARD OF DIRECTORS MEETING—Onondaga Hotel

5:00 pm CONVENTION CLOSES.

THE TECHNICAL PROGRAM

THE story of Statistical Quality Control is spreading throughout industry the world over. Everyone connected with engineering, management, purchasing, research, teaching, and of course, inspection, will eventually hear this story and become affected by it to some degree. The only place you can hear all facets of the story discussed by recognized leaders in the field is at the imminent Sixth Annual Convention of the American Society for Quality Control. The program of technical papers, basic educational sessions, and varied and colorful exhibits, combined with the social events and other highlights of the three day meeting, are set forth in what follows.

Period I—Series A

Subject: General Interest.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: Statistical Analysis of Variability and Measurement Error.
Moderator: Dorothy L. Biggs, *Cutter Laboratories.*

SPEAKER: Thomas A. Budne, *Control Statistician, Quality Control Division, E. R. Squibb & Sons.*
SUBJECT: "The Error in Measurement"
SPEAKER: Frank E. Grubbs, *Chief, Surveillance Branch, Ballistic Research Laboratories, Aberdeen Proving Ground.*
SUBJECT: "Some Examples of Statistical Methods in Army Ordnance"

Period I—Series B

Subject: A Receiving Inspection Department.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: Inspection of Samples of Incoming Lots of Material Is a Function of the Receiving Department. The Organization and Operation of the Department Involves More Than Inspection.
Moderator: John A. Henry, *Professor of Mechanical Engineering, University of Illinois.*

SPEAKER: A. R. Jackson, *Director of Quality Control, Allen B. Wrisley Company.*
SUBJECT: "A Complete Story of the Operation of a Receiving Department"

Period I—Series C

Subject: Precision Manufacture.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: Quality Control of Close Tolerances.
Moderator: Paul C. Clifford, *Associate Professor, Montclair State Teachers College.*

SPEAKER: Orrin W. Hitchcock, *Quality Manager, Scintilla Magneto.*
SUBJECT: "Quality Control in Precision Manufacture"
SPEAKERS: Ellis R. Ott, *Professor of Mathematics, Rutgers University,* and August B. Mundel, *Chief Engineer, Quality Control and Inspection Division, Sonotone Corporation.*
SUBJECT: "Narrowed-Limit Gages"

Period I—Series D

Subject: What Is the Quality Control Job?
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: The Place Occupied by Quality Control in Industrial Plants and the Qualifications of Quality Control Personnel.
Moderator: Joseph M. Juran, *President, J. M. Juran Consulting Management Engineers, Editor Quality Control Handbook, and Professor of Management Engineering, New York University.*

QUESTION A: What Is the Role of the Quality Control Department with respect to:

(1) The Company's Quality Policy?
(2) The Specification of Quality?
(3) Vendor Relations?
(4) Customer Relations?
(5) Plant Processes?
(6) Inspection?
(7) Defect Prevention?
(8) Statistics?

QUESTION B: What are the Attributes and Qualifications of:

(1) The Chief of the Quality Control Department?
(2) The Quality Control Engineer?

Panel members:

Ernest H. Robinson, *Director of Quality Control, Johnson & Johnson.*
Hugh M. Smallwood, *Research Chemist, U. S. Rubber Company, General Laboratories.*
Raymond S. Saddoris, *Director of Quality, A. O. Smith Corporation.*

Every Industrial Company faces the questions this panel will answer. Discussion from the floor will be a part of this meeting.

Period I—Series E

Subject: Chemical Industry.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: Statistical Approach to Manufacturing and Sampling Problems in Chemical Processing.
Moderator: Roland H. Noel, *Director of Product Coordination, Bristol Laboratories, Inc.*

SPEAKER: Carl A. Bennett, *Chief Statistician, General Electric Company, Richland, Washington.*
SUBJECT: "Statistical Approach to Chemical Processing Problems"
SPEAKER: Bernard H. Lloyd, *Engineering Specialist in Statistics, Canadian Industries Limited.*
SUBJECT: "Statistical Approach to Bulk Sampling Problems"

Period I—Series F

Subject: Aircraft Industry.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: Problems of the Aircraft Industry, Internal as Well as Those Encountered in Meeting Government Standards.
Moderator: Dorian Shainin, *Chief Inspector, Hamilton Standard Division, United Aircraft Corporation.*

SPEAKER: H. Earle Moore, *Chief Inspector, McDonnell Aircraft Corporation.*
SUBJECT: "Quality Control Programs in the Aircraft Industry"
SPEAKER: Fay Carlson, *Supervisor of Statistical Methods, Sundstrand Machine Tool Company.*
SUBJECT: "A Survey of the Application of Mil-Std-105A in the Aircraft and Associated Industries"

Period I—Series G

Subject: Textile Industry.
Time: Thursday, May 22, 2-4 P.M.
Place: War Memorial Auditorium
Theme: An Initial Presentation at National Level of the Control Problems and Statistical Practice of the Textile Industry.
Moderator: Robert R. Jones, *Quality Control Superintendent, Bigelow-Sanford Carpet Co., Inc.*

SPEAKER: John H. Reynolds, *Technical Control Statistician, Celanese Corporation of America.*
SUBJECT: "Controlling the Control Laboratories in a Chemical Fiber Manufacturing Plant"
SPEAKER: D. S. Hamby, *Assistant Professor, School of Textiles, North Carolina State College.*
SUBJECT: "Quality Control in Staple Fiber Manufacturing Processes"

Period II—Series A

Subject: General Interest.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: New Techniques for Control Charting and for Production Trouble Shooting.
Moderator: C. E. Fisher, *Member of Technical Staff, Bell Telephone Laboratories, Inc.*

SPEAKER: Leonard A. Seder, *Chief Quality Control Engineer, Gillette Safety Razor Company.*
SUBJECT: "The Technique of Preventing Defectives"
SPEAKER: Enoch B. Ferrell, *Switching Research Engineer, Bell Telephone Laboratories, Inc.*
SUBJECT: "Control Charts Using Mid-Ranges and Medians"

Period II—Series B

Subject: An Evaluation of the Use of Mil-Std-105A.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: A Discussion of the Operation of Mil-Std-105A in which Industry and Armed Forces Representatives Present Their Points of View. The audience will presumably participate.
Moderator: Besse B. Day, *Principal Statistician, U. S. Naval Engineering Experiment Station.*

SPEAKER: William R. Pabst, Jr., *Chief Statistician, Navy Department Bureau of Ordnance.*
SUBJECT: "An Introduction to Military Inspection"
SPEAKER: John W. W. Sullivan, *Metallurgist, American Iron & Steel Institute.*
SUBJECT: "Applicability and Inapplicability of Mil-Std-105A"
SPEAKER: Captain B. L. Lubelsky, U. S. N., *Navy Department Bureau of Ordnance.*
SUBJECT: "Navy-Industry Relationship"

Period II—Series C

Subject: Factory Operation and the Gage Laboratory.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: Raw Material Saving Through Control Charts and a Detailed Program for the Establishment of a Gage Laboratory.
Moderator: Francis B. Murphy, *Field Manager, Johnson Gage Company.*

SPEAKER: Howard R. Bolton, *Assistant Superintendent of Inspection, Harrison Radiator Division, General Motors Corp.*
SUBJECT: "The Use of a Control Chart to Reduce Material Consumption"
SPEAKER: Clifford A. Wallace, *Director of Quality Control, Eastman Kodak Company, Camera Works.*
SUBJECT: "The Gage Laboratory, Its Equipment and Function, to Accomplish Precision—An Ever-Ascending Spiral Toward Perfection"

Period II—Series D

Subject: Quality Control Education.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: Broad Coverage: College and University Curricula, Extension Programs, In-Plant Training, Educational Activities of the Society and Its Sections.
Moderator: A. C. Richmond, *General Supervisor of Inspection Methods Research, International Harvester Co.*

SPEAKER: John A. Henry, *Professor of Mechanical Engineering, University of Illinois.*
SUBJECT: "A Survey and Evaluation of Types of Quality Control Education"
SPEAKER: Edwin G. Olds, *Professor of Mathematics, Carnegie Institute of Technology.*
SUBJECT: "The Need for Statistical Quality Control in Engineering Education"

Period II—Series E

Subject: Chemical Industry.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: Advanced Experimental Techniques for Use in Chemical Research and Development.

Moderator: Hugh M. Smallwood, *Research Chemist, U. S. Rubber Company, General Laboratories.*

SPEAKER: Charles A. Bicking, *Ordnance Engineer, Research and Development Division, Office of the Chief of Ordnance (Army) Department of Defense.*

SUBJECT: "Some Uses of Statistics in the Planning of Experiments"

SPEAKER: Edwin C. Harrington, Jr., *Manager of Industrial Statistics, Monsanto Chemical Company.*

SUBJECT: "Increasing the Efficiency and Economy of Experimentation"

Period II—Series F

Subject: Electronics and Electrical Industry.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: A Composite Program Dealing Separately with the Vendor Certification Problem and In-Plant Control Technique.
Moderator: Frederick Trowbridge, *Quality Control Engineer, Sentinel Radio Corp.*

SPEAKER: M. E. King, *Engineer, Quality Control Division, Bureau of Ordnance, Navy Department.*

SUBJECT: "Vendor Certification by Established Standards"

DISCUSSOR: August B. Mundel, *Chief Engineer, Quality Control and Inspection Division, Sonotone Corporation.*

SUBJECT: "Examples of Vendor Certification"

SPEAKER: Harry G. Romig, *Quality Manager, Hughes Aircraft Company.*

SUBJECT: "Quality Control Techniques for Electronic Components"

Period II—Series G

Subject: Steel Furnace and Foundry Industry.
Time: Friday, May 23, 10-12 A.M.
Place: War Memorial Auditorium
Theme: Statistical Analysis of Steel Processing and Foundry Operation.
Moderator: Walter L. Hodapp, *Supervisor of Wiremill Metallurgical Laboratory, Crucible Steel Company of America.*

SPEAKER: Richard H. Ede, *Process Metallurgist, U. S. Steel Company.*

SUBJECT: "Quality Control of Steel Manufacture"

SPEAKER: Allen A. Evans, *Quality Control Engineer, International Harvester Company.*

SUBJECT: "Quality Control and Foundry Practice"

Period III—Series A

Subject: General Interest.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: The Application of Statistical and Probability Techniques to the Analysis of Office and Government Records.
Moderator: Julian H. Toulouse, *Chief Engineer, Quality and Specification Department, Owens-Illinois Glass Company.*

SPEAKER: Howard L. Jones, *General Supervisor of Statistics, Illinois Bell Telephone Company.*

SUBJECT: "Some Problems in Sampling Accounting Records"

SPEAKER: A. C. Rosander, *Statistician, Bureau of Internal Revenue, U. S. Treasury Department.*

SUBJECT: "Probability Statistics Applied to the Control of Tax-Return Operations"

Period III—Series B

Subject: Mil-Q-5923A
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: An Explanation and Appraisal of Specification Mil-Q-5923A (USAF) From the Points of View of the Air Force and the Manufacturers of Military Aircraft and Equipment.
Moderator: F. J. Halton, Jr., *Assistant to the President, Deere & Company.*

SPEAKER: Brigadier General Walter G. Bain, USAF, *Chief, Quality Control Division, Air Materiel Command, Wright-Patterson Air Force Base.*

SUBJECT: "The Air Force Quality Control Specification Mil-Q-5923A (USAF) Provides a Definite Standard."

SPEAKER: J. H. Sidebottom, *Assistant Director, Technical Service, Aircraft Industries Association.*

SUBJECT: "Military Inspection in the Aeronautical Field; An Appraisal of Mil-Q-5923A"

Period III—Series C

Subject: Engineering, Stamping Industry.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: What Quality Control Can Do for Engineers: An Initial Presentation of Quality Control in The Die Stamping Industry.
Moderator: Kenneth Rosengren, *Quality Manager, Houdaille-Hershey Corporation, Buffalo.*

SPEAKER: Walter S. Oliver, *Quality Manager, Detroit Gear Division, Borg-Warner Corporation.*

SUBJECT: "Statistical Quality Control in Relation to Engineering"

SPEAKER: Robert B. Griffith, *Quality Control Manager, Bossert Company, Division of Timken-Detroit Axle Company.*

SUBJECT: "Quality Control Means Less Salvage and Scrap"

Period III—Series D

Subject: Selling Quality Control.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: How to Present the Quality Control Story at Operating Levels.
Moderator: Ellis R. Ott, *Professor of Mathematics, Rutgers University.*

SPEAKER: Harry E. Thompson, *Manager of Quality Control, Anaconda Wire and Cable Company.*
SUBJECT: "Achieving Quality-Mindedness Through Employee Communications"
SPEAKER: Paul C. Clifford, *Associate Professor, Montclair State Teachers College.*
SUBJECT: "Using Training Conferences As a Quality Control Catalyst"

Period III—Series E

Subject: Mathematical Statistics.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: The Background of Quality Control Lies in Mathematical Statistics.
Moderator: Max Astrachan, *Professor of Statistics, USAF Institute of Technology.*

SPEAKER: Daniel B. DeLury, *Director, Department of Mathematical Statistics, Ontario Research Foundation.*
SUBJECT: "Designing Experiments to Isolate Sources of Variation"
SPEAKER: Irving W. Burr, *Professor of Mathematics, Research Associate in Statistical Laboratory, Purdue University.*
SUBJECT: "Fundamental Principles of Sequential Analysis"

Period III—Series F

Subject: Food Industry.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: An Initial Presentation Nationally of the Attitude and Special Quality Control Problems of the Food Industry.
Moderator: Frank V. Kenney, *Assistant Technical Director, P. Ballantine & Sons.*

SPEAKER: Stephen Harrison, *Biometrician, Research Laboratories, Kraft Foods Company.*
SUBJECT: "The Use of Statistics in Food Processing"
SPEAKER: David R. Peryam, *Chief, Acceptance Division, Food Laboratories, Quartermaster Food and Container Institute.*
SUBJECT: "Perception, Preference, Judgment—Cues to Food Quality"

Period III—Series G

Subject: Automotive Industry.
Time: Friday, May 23, 3-5 P.M.
Place: War Memorial Auditorium
Theme: Quality Control in the Production of a Complex Assembly: An Automobile.
Moderator: J. Clayton Knapp, *Superintendent Quality Control, Ford Motor Company of Canada Limited.*

SPEAKER: Glenn U. Hinds, *Statistical Quality Control Engineer, Buick Motor Division, General Motors Corporation.*
SUBJECT: "Pressed Metal — In Process Control Techniques"
SPEAKER: Nelson G. Meagley, *Manager, Statistical Quality Control, Willys-Overland Motors.*
SUBJECT: "Engineering the Inspection of Manufacturing Processes"

Period IV—Series A

Subject: General Interest.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: Methods of Training in Operating Areas With Emphasis on the Human Side.
Moderator: Leonard A. Seder, *Chief Quality Control Engineer, Gillette Safety Razor Company.*

SPEAKER: Edward A. Reynolds, *Quality Manager, Conmar Products Corporation.*
SUBJECT: "Methods of Company Training for Quality Engineers and Supervisors"
SPEAKER: J. Frederick Verigan, *Quality Control Engineer, Atlas Powder Company.*
SUBJECT: "The Operator is Interested"

Period IV—Series B

Subject: Inspection.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: A Report on Some Newer Ideas in Receiving and In-Process Inspection.
Moderator: Roy A. Wylie, *Quality Control Engineer, Woodward Governor Company.*

SPEAKER: Truman W. Read, *Assistant to Chief Enspector, Technical, Hamilton Standard Division, United Aircraft Corporation.*
SUBJECT: "The Continuous Lot Plot Plan"
SPEAKER: Dorian Shainin, *Chief Inspector, Hamilton Standard Division, United Aircraft Corporation.*
SUBJECT: "VOSP—A New Invention For Averaging Out Human Opinion In Visual Inspection"

Period IV—Series C

Subject: History, Psychology, and Human Beings.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: A Presentation of Some Different Points of View Concerning Quality Control.
Moderator: Raymond S. Saddoris, *Director of Quality, A. O. Smith Corporation.*

SPEAKER: Paul J. Mundie, *Consulting Psychologist, Humber and Mundie.*
SUBJECT: "Psychological Factors in Selling Quality Control"
SPEAKER: George L. Diggles, *Manager, Lamp Inspections for Manufacturers, Director of Electrical Testing Laboratories.*
SUBJECT: "Early Development of the Statistical Method of Sampling in Industry"

Period IV—Series D

Subject: Textile Machinery Industry.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: Installing and Operating a Quality Control System in a Machine Shop.
Moderator: John F. Greacen, *Chief Inspector, The Bristol Company.*

SPEAKERS: John T. MacDougall, *Chief Inspector, Saco-Lowell Shops,* and William G. Cunningham, *Quality Control Supervisor, Saco-Lowell Shops.*

SUBJECT: "Applications of Statistical Quality Control in a Machine Shop Manufacturing Textile Machinery"

Period IV—Series E

Subject: Pulp and Paper Industry.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: A Statistical Approach to the Control of Quality and Cost in the Processing of Paper.

Moderator: Howard L. Jones, *General Supervisor of Statistics, Illinois Bell Telephone Company.*

SPEAKER: Warren R. Purcell, *Quality Control Manager, Brown Company.*

SUBJECT: "The Quality Control Engineer in the Pulp and Paper Industry"

SPEAKER: Carl E. Noble, *Superintendent of Customer Acceptance Laboratories, Kimberly-Clark Corporation.*

SUBJECT: "Statistical Cost Control in the Paper Industry"

Period IV—Series F

Subject: Electronics and Electrical Industry.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: Operations in the Electrical Segment of the Industry and A Critical Survey of the Consumer-Vendor Relation Problem.

Moderator: Dean K. Richman, *Division Manager of Quality Control, Sylvania Electric Products Inc., Buffalo.*

SPEAKER: Wyatt H. Lewis, *Quality Control Supervisor, General Electric Company, Ontario, California.*

SUBJECT: "Special Applications for Control Charts"

SPEAKER: J. Philip Worth, *Chief Inspector, Electrolux Corporation.*

SUBJECT: "The Consumer-Vendor Relationship—A Mutual Responsibility"

Period IV—Series G

Subject: Automotive Industry.
Time: Saturday, May 24, 9:30-11:30 A.M.
Place: War Memorial Auditorium
Theme: A Composite Program Dealing with Methods of Controlling Small Lot Precision Manufacture and an Application of the Vendor Certification Principle.

Moderator: W. H. Coughlin, *Assistant Quality Manager, Thompson Products, Inc.*

SPEAKER: J. N. Berrettoni, *J. N. Berrettoni and Associates.*

SUBJECT: "Controlling Quality During Manufacturing of Small Lots"

SPEAKER: Robert M. Currie, *Assistant Manager, Analysis Department, Quality Control, Manufacturing Staff, Ford Motor Company.*

SUBJECT: "The Ford Program for Vendor Certification of Quality Level"

Periods I-II-III-IV

Subject: Educational Program.
Time: Thursday, May 22, 2-5 P.M.; Friday, May 23, 9-12 A.M. and 3-5 P.M.; Saturday, May 24, 9-12 A.M.
Place: War Memorial Auditorium
Theme: An Integrated Presentation of the Fundamentals of Quality Control: Principles and Examples of Application.

INSTRUCTIONAL STAFF: Arthur Bender, Jr., *Quality Engineer, Delco-Remy Division, General Motors Corp.*
George W. McDermott, *Supervisor of Statistics and Analysis, Delco-Remy Division, General Motors Corp.*
Edward Oakley, *General Motors Institute.*

SUBJECT MATTER: "Fundamentals and Frequency Distributions"
"Control Charts for Variables"
"Control Charts for Attributes"

EXHIBITORS

A varied and instructive group of exhibitors has already contracted for space to show their Quality Control equipment and methods of controlling quality. A partial list of these companies is given here.

Bausch and Lomb Optical Company
Boice Manufacturing Co.
Brown and Sharpe Manufacturing Co.
Brush Development Co.
Carrier Corporation
Collins Micro Flat Co.
Cosa Corporation
Do-All Co.
Elliott Service Co.
Engineer Specialties Div., Universal Engraving and Colorplate Co.
Federal Products Corporation
Ford Motor Co.
Friden Calculating Machine Co.
General Electric Co.
Graham-Mintel Instrument Co.
Greenfield Tap and Die Corp.
Johnson Gage Co.
Jones and Lamson Machine Co.
L. S. Starrett Co.
Magnaflux Corp.
Marchant Calculating Machine Co.
Monroe Calculating Machine Co.
National Tool Co.
Physicists Research Co.
Pratt and Whitney Div., Niles-Bemont-Pond Co.
Sheffield Corp.
Sylvania Electric Co.
Taft-Pierce Mfg. Co.

LADIES PROGRAM

A fine series of events has been scheduled for those ladies who do not wish to attend the regular meetings of the Convention. Starting on Thursday afternoon, with a walking tour of the world famous Onondaga Pottery, the program continues with luncheon Friday at Tubbert's, followed by a highly entertaining and edifying talk on "Bugs and Drugs." The ladies will also be heartily welcomed to the Annual Banquet and the Convention Social Evening, if they desire to attend.

TRANSACTIONS

Since you will probably be able to attend only four of the technical sessions yourself, you will wish to have the attractively bound copy of all the technical papers. The Transactions booth in the Exhibit Area will provide you a copy for $3.00.

BOOK BOOTH

The old and the new in statistical and quality control literature will be available at the Book Booth. At least nine authors and as many other experts in the field will be available at different times to advise you on the purchase of the books you need.

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The Interpretation of Chemical Data*

W. J. YOUDEN
National Bureau of Standards

INTRODUCTION

The usefulness of statistical methods for the interpretation of chemical data is, in general, best illustrated by selecting a particular chemical problem and showing in some detail the appropriate statistical operations on the data. Reliance is then placed on the hope that chemists will recognize similar chemical situations and apply the same statistical technique. Unfortunately the numerical procedures are sometimes literally copied without a clear understanding of the statistical ideas involved. Statistical formulas are usually put in a form to facilitate the arithmetical operations, and this often conceals the thoughts underlying these formulas. The numerical operations in this paper are intended to reveal the ideas behind one statistical technique which has wide areas of application. It is reasonable to expect that more chemists will use statistical techniques and with greater confidence in the statistical verdicts if the logic of the statistical procedure is understood.

MEASURES OF VARIATION

There are numerous ways of expressing the fact that repeated measurements of the same quantity do not yield exactly the same result. It is common practice, if just two measurements are available, to state the difference between the duplicate measurements. When larger sets of data are examined the arithmetical average of the set is first found and then the absolute difference taken between each measurement and the average. Th average value of these differences is found and this is called the average deviation. This is a popular procedure among chemists. The average deviation is subject to certain awkward limitations and the statistician prefers to square the differences, sum these squares, divide by one less than the number of measurements, and extract the square root. The result is called the "standard deviation". This measure is more work to compute but the advantages are worth the additional labor of computation. A simple numerical example is given in Table 1.

TABLE 1—**Measures of Variation**

	Data	Absolute Difference	Square of Difference
	1.04	.01	.0001
	1.08	.03	.0009
	1.03	.02	.0004
	1.06	.01	.0001
	1.04	.01	.0001
Sum	5.25	.08	.0016

Av. = 1.05

$$\text{Average deviation} = \frac{0.08}{5} = 0.016$$

$$\text{Standard dev.} = \sqrt{\frac{0.0016}{4}} = 0.020$$

The existence of several methods of measuring variation should occasion no surprise to chemists who have devised a whole list of methods of expressing the concentration of a substance in solution. The concentration may be expressed as percent by weight or volume, or molar concentration, or pH, or other unit. It is proper to expect the statistician to show the chemist why the standard deviation is the desirable unit to express variation. The chemist will be more inclined to use this unit if he is convinced that by its use he can make a more searching examination of his data.

WHY STATISTICIANS USE THE STANDARD DEVIATION

Given a set of repeated measurements of the same quantity they will usually cluster more or less symmetrically about the arithmetic average of the set. The various units for measuring the variation among measurements all serve the purpose of providing a measure of how tightly the individual measurements cluster about the average. For large sets of data the standard deviation turns out to be approximately 1.25 times as large as the average deviation. Mathematicians have shown that if a very large set of data is arbitrarily split up into many sub-sets and the average deviation and standard deviation computed for every sub-set, then the various values for the standard deviation are in closer agreement among themselves than are the values for the average deviation. Consequently if only one sub-set is available the standard deviation may be expected to give a better estimate of the variation of the whole set than will be obtained using the average deviation.

TABLE 2—**Twenty-One Individual Measurements**

								Av.
	8.99	9.09	8.76	8.93	9.29	8.48	8.77	8.901
	8.39	8.71	9.27	8.85	8.76	8.32	9.23	8.790
	8.34	8.78	8.18	8.88	8.87	8.86	9.02	8.704
Av.	8.57	8.86	8.74	8.89	8.97	8.55	9.01	8.799

*Presented before the Fifth Annual ASQC Convention, May 23, 1951, Cleveland, Ohio.

AN IMPORTANT PROPERTY OF THE STANDARD DEVIATION

The variation exhibited by the individual measurements in a set of repeated measurements is concisely summarized by the standard deviation. If the individual measurements are now grouped in pairs and the average found for each pair, a familiar result is obtained. The pair averages display a smaller variation among themselves than the variation shown by the individual measurements. In fact the standard deviation for the pair averages may be closely predicted by dividing the standard deviation for the individual measurements by the $\sqrt{2}$. This is merely a particular case of the widely known general rule which states that the standard deviation of the average of n measurements is found by dividing the standard deviation of the individual measurements by the $\sqrt{n}$. It is this rule which will be used in the following discussion of a set of measurements. It will be used in the reverse order from the way the rule is stated, i.e., it will be used to estimate the standard deviation of individual measurements by multiplying by the $\sqrt{n}$ the standard deviation calculated from a set of averages, where each average is based upon n measurements.

EXAMINATION OF A SET OF MEASUREMENTS

Suppose that 21 measurements of the same quantity are available. Such sets of measurements arise in a multitude of ways. They may be the percent yield or percent impurity in 21 batches in a production process. The study of an analytical procedure often leads to a fairly lengthy series of repeated measurements for the direct purpose of ascertaining the precision. Sometimes a sample of material is analyzed by several laboratories each making two or three or more determinations. For the moment consider that the following measurements (Table 2) are presumably all measurements of the same quantity. They are listed in seven columns, each column with three entries. Defer for the moment, any inquiry regarding the basis for this grouping of the measurements. The average for each column is shown below the column and the average across each row is shown at the right.

The idea may occur to the chemist to compute the standard deviation for the seven column averages and to compute also the standard deviation for the three row averages. It would be expected that the row averages, being based upon seven measurements, would show less variation and therefore have a smaller standard deviation than the column averages which are based upon only three measurements. It seems logical to multiply the standard deviation computed from the rows by the $\sqrt{7}$ and thus, by the rule, obtain an estimate of the standard deviation of the individual measurements. Similarly, multiplying the standard deviation found for the column averages by the $\sqrt{3}$ should be an alternative way of obtaining an estimate of the standard deviation of the individual measurements. There is only the one set of 21 measurements so that these two procedures should be expected to come out with approximately the same result for the standard deviation of the individual measurements. As a matter of curiosity suppose these numerical operations are performed leading to the results in Table 3.

TABLE 3

	Standard Deviation	Multiply by	Estimated S.D. for Individual Measurements
Rows	0.09876	$\sqrt{7}$	0.2613
Cols.	0.18425	$\sqrt{3}$	0.3191

TABLE 4—**Critical F Ratios—5 Percent Level**

	Degrees of Freedom	For Numerator					
		1	2	3	4	5	6
For Denominator	2	18.51	19.00	19.16	19.25	19.30	19.33
	4	7.71	6.94	6.59	6.39	6.26	6.16
	8	5.32	4.46	4.07	3.84	3.69	3.58
	9	5.12	4.26	3.86	3.63	3.48	3.37
	12	4.75	3.88	3.49	3.26	3.11	3.00
	16	4.49	3.63	3.24	3.01	2.85	2.74
	20	4.35	3.49	3.10	2.87	2.71	2.60
	24	4.26	3.40	3.01	2.78	2.62	2.51

The Table is entered with Degrees of Freedom equal to one less than the number of rows and columns.

This Table is extracted from Fisher and Yates "Statistical Tables for Biological, Agricultural and Medical Research."

The next thing to make clear is that it would be extremely convenient to have at hand a means of comparing these two estimates of the standard deviation of the individual measurements. One important reason for wishing to compare these two estimates is that it is possible to conceive of a situation in which these two estimates could be expected to disagree. Suppose, for example, all three measurements in the first column are individually increased by 1.40. The result of this is to raise the average of the first column by 1.40 leaving the other column averages unaltered. Quite a different result is obtained for the row averages. Since all row totals will be raised by 1.40, all three averages will go up by 0.20. The standard deviation of the row averages is left unaltered by this constant addition to each row average. The standard deviation for the column averages is substantially increased by the increase of 1.40 in the average for the first column. The new estimate is $\sqrt{3}$ x 0.4553 or .7886 as compared with the previous value of 0.3191.

The following things should be apparent:

(a) that any constant increment to the measurements in a column does not affect the standard deviation for the rows.

(b) that one or more columns may undergo such constant additions or subtractions, the amounts being different for different columns without altering the standard deviation computed for the rows.

(c) that if it should be possible to appraise or detect a difference between the two estimates of the standard deviation for the individual measurements, this would provide a basis for deciding that some sort of difference existed between the columns. This would be important if, in arranging the data in the table, the columns corresponded to triplicate analyses reported by seven different laboratories, or to successive batches by seven different machines.

(d) that exactly the same arguments may be carried out by supposing some constant addition to all the entries in a given row.

So long as it is known that in the arrangement of the data the possibility of constant additions is restricted to either rows or columns the interpretation of a disparity between the two estimates for the standard deviation of individual measurements is quite simple. It is necessary to call upon statistical tables to provide a guide for passing judgment upon the two estimates of the standard deviation. If the columns are suspected of being subject to constant additions the following ratio is computed:

$$\frac{\left(\begin{array}{c}\text{square of standard dev.}\\ \text{as estimated from columns}\end{array}\right)}{\left(\begin{array}{c}\text{square of standard dev.}\\ \text{as estimated from rows}\end{array}\right)}$$

This ratio is called F. Note that it was not really necessary to go through the step of taking the square root since this ratio is in terms of the squares of the standard deviations. Tables provide critical ratios for F, for various numbers of rows and columns, which are rarely exceeded if there are no constant additions to the column entries. The F ratio for columns to rows before the addition of the constant to the first column was 0.1018/0.0683 or 1.490 and after the addition of the constant the F ratio became 0.6219/0.0683 or 9.105. The F ratio does not exceed 19.3, the five percent critical value given in the F table. (See Table 4.)

Chemists will not be slow to point out that both columns and rows may be subject to constant additions and therefore both numerator and denominator of the above ratio would increase and the ratio would fail as a measure of detecting experimental effects. Obviously what is needed is a third estimate of the standard deviation of the individual measurements which would be immune to the row and column additions. It is very easy to obtain this further estimate and it is the one normally used in the denominator of the F ratio. A separate F ratio is then computed for both rows and columns.

It will now be shown that there does exist a means of computing an estimate of the standard deviation of the individual measurements even if both rows and columns have undergone additions of constant quantities. For simplicity, consider the special case where the number of rows is equal to the number of columns. Arrange nine measurements all of the same quantity in a square as follows:

				Av.
	x_1	x_2	x_3	$\bar{x}$
	x_1'	x_2'	x_3'	$\bar{x}'$
	x_1''	x_2''	x_3''	$\bar{x}''$
Av.	$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_3$	

Now add a constant a to all entries in the first row and a constant b to all entries in, say, the second column, obtaining Table 5.

These additions alter the standard deviations of both row and column averages. How then will it be possible to form an estimate that has not been altered by these additions? The answer is simple. Form averages by collecting the data according to the following schedule:

ABC Av. for A $= \bar{x} + a/3 + b/3$
CAB Av. for B $= \bar{x} + a/3 + b/3$
BCA Av. for C $= \bar{x} + a/3 + b/3$

TABLE 5

				Av.
	$x_1 + a$	$x_2 + a + b$	$x_3 + a$	$\bar{x} + a + b/3$
	x_1'	$x_2' + b$	x_3'	$\bar{x}' + b/3$
	x_1''	$x_2'' + b$	x_3''	$\bar{x}'' + b/3$
Av.	$\bar{x}_1 + a/3$	$\bar{x}_2 + b + a/3$	$\bar{x}_3 + a/3$	

TABLE 6—**Tabulation of Results**

Standard Deviation Estimated from		Square of S.D.	F ratio	Critical ratios	Degrees of Freedom
Rows	= 0.2613	0.0683	0.677	3.88	(r-1) = 2
Cols.	= 0.3191	0.1018	1.009	3.00	(c-1) = 6
Indirectly	= 0.3176	0.1009			(r-1)(c-1) = 12

Thus all three averages have been increased by the same composite constant quantity $(a + b)/3$ and the averages will yield exactly the same estimate of the standard deviation for these diagonal averages as was obtained before the addition of the constants.

There remains only the task of indicating how to obtain this estimate of the standard deviation in the general case where the numbers of rows and columns are different. The following symbols will be used:

s_r^2 = square of standard deviation computed for r rows = 0.009754
s_c^2 = square of standard deviation computed for c columns = 0.03395
s_t^2 = square of standard deviation computed for all the data = 0.09792

The last item is computed by ignoring completely the row, column classification. The average for all the measurements is computed. The difference between this grand average and every individual measurement is squared and the sum of these squares is found. This sum when divided by one less than the total number of measurements gives s_t^2.
Compute: $(rc-1)s_t^2 = 1.9583$
Compute: $c(r-1)s_r^2 + r(c-1)s_c^2$
$= 0.1366 + 0.6111 = 0.7477$

The difference 1.2106 between these quantities when divided by (r-1)(c-1) or 12 gives $s_e^2 = 0.1009$. This is the estimate of the square of the standard deviation of the individual measurements which is immune from any constant components present in either the rows or columns.

Extracting the square root gives 0.3176 for the third estimate of the standard deviation. (See Table 6.)

The F ratios are both near unity and are found to be less than the respective critical values taken from the F table. The critical value for F is found by entering the table at the top with (c-1) and at the left with (r-1)(c-1) for columns. For rows the table is entered at the top with (r-1) and at the left with (r-1)(c-1). The conclusion in this case is that the set of measurements is homogeneous, in other words that the variation among the row averages and also among the column averages is in keeping with the variation of the measurements as revealed by the estimate which is not influenced by any constant row or column effects if present.

If these computations are repeated for the same data after the addition of 1.40 to the entries in the first column, the calculated F ratio for columns becomes 6.16. This is well in excess of 3.00, the five percent critical value, and even exceeds 4.82, the one percent critical value. The verdict would then be that there does exist a significant difference among the column averages.

APPLICATION TO EXPERIMENTAL RESULTS

It is usually the case that the grouping of data into columns and rows corresponds to classifications arising in the experimental work. For example, counts may be made with a Geiger counter on four samples of radium.* If the four samples are run consecutively, the four counts may be called Experiment 1. The experiment may be repeated as often as desired, varying the order of the samples in each experiment. The results of such an investigation are shown in Table 7 which gives the net counting rates per second, diminished by 25.00.

The experimenter is interested to know whether these data constitute evidence of differences between the radium samples. He would also like to know the precision of comparisons between samples.

Inspection shows that the sample averages vary more than the averages for the different experiments.

*H. H. Seliger, A New Method of Radioactive Standard Calibration. Journal of Research of the National Bureau of Standards, 45, 496-502, 1950.

TABLE 7—**Net Counting Rates Less 25.00**

Sample Number	Experiment Number				Sample Average
	1	2	3	4	
A	1.46	2.00	1.48	1.51	1.61
B	2.58	3.03	2.82	2.90	2.83
C	4.15	4.61	4.31	4.13	4.30
D	4.54	4.52	4.53	4.15	4.44
Exper. Av.	3.18	3.54	3.28	3.17	

TABLE 8

Standard Deviation Estimated from	Square of S. D.	F ratio	5% level for F*
Samples = 2.6719	7.1391	298.7	3.86
Experiments = 0.3419	0.1169	4.89	3.86
Diagonals = 0.1546	0.0239	-	

*Three and nine degrees of freedom.

It is possible that the line voltage or other conditions which influence the counting rate varied from experiment to experiment. In that case the variation shown by the experiment averages is greater than would have been the case if all conditions influencing the counting rate could have been held constant over all four experiments. This will be revealed by calculating the estimate of the standard deviation which is independent of any differences between samples or any constant differences between experiments.

Calculating the three estimates of the standard deviation shows that samples and experiments give larger estimates than the diagonal averages. The F ratios exceed the tabulated critical value and supply convincing evidence of differences between samples and persuasive evidence of differences between experiments. (See Table 8.)

It was previously seen that differences between row (sample) averages are unaffected by constant differences between columns (experiments). Consequently the precision of the sample comparisons is not diminished by the existence of such differences between experiments. When the measurements are grouped as above in separate experiments the proper estimate of the precision is obtained from the diagonal averages, in this case, 0.1546. If, as is often done, the precision is calculated directly from the four measurements on sample A, the four on sample B, etc., a larger estimate (0.2168) is obtained. The larger value may lead to overlooking real differences between samples, and does not do justice to the real precision of the work which has been improved by taking the measurements in blocks, here called experiments.

SUMMARY

The whole discussion has been based upon the standard deviation as a measure of variation and the simple rule relating the standard deviation of an average to the standard deviation of the individual measurements entering into the average. Whenever measurements are arranged in a rectangular array it is possible to arrive at three separate estimates of the standard deviation. One estimate is based upon the row averages, a second upon the column averages, and the third upon some complicated diagonal averages so chosen as to be unaffected by constant additions to the entries in the columns or rows. It is logical to expect, if the classification of the data into the rows and columns results in no pattern in the dispersion of the measurements, that the row and column averages will lead to estimates of the standard deviation which are compatible with the third estimate. The statistician has tables of the ratio F to appraise the row and column estimates in terms of the estimate which is immune from constant row or column additions.

All the foregoing describes a rather clumsy bit of arithmetic for reaching the same numerical results (F ratios) that are achieved by a series of neat computations under the heading: The Analysis of Variance.

Production Research in the Manufacture of Hearing Aid Tubes*

DORIS ROSENBERG FRED ENNERSON
Sonotone Corporation

A VERY important function of a variables control chart in the manufacture of any product is to indicate a trend toward a better or an inferior product. This is always true, but it becomes especially valuable when some of the significant controlling factors in the process have not been definitely identified and when the method of correcting an unfavorable situation or of continuing a favorable one is not entirely known.

The controlling factors in some production operations are well known or are easily recognizable. An obvious example might be the inadvertent use of the wrong raw materials or material whose chemical content is inferior in quality. Tool wear and operator fatigue are frequently easy to recognize as assignable causes which affect quality levels. But in many industrial processes, the important controlling factors are unknown or at least partially unknown; also, it is often advisable to change the combination of factors during a manufacturing run. In these latter cases, the use of properly designed production experiments will increase the speed and efficiency with which a satisfactory combination of manufacturing conditions can be obtained.

Sonotone Corporation manufactures hearing aids. It also manufactures the tubes which are an integral part of them. Thus, an electron tube is only one of many sub-assemblies which Sonotone manufactures to fulfill its main function of manufacturing hearing aids.

The manufacture of electron tubes is an example of an industrial process in which controlling factors are frequently difficult to recognize or are unknown; the industry is still an art in many respects. The factors controlling the dozen or so different characteristics which are considered important for a particular tube type often seem incapable of adjustment to meet all the specifications, and require numerous compromises. (Sometimes the compromises become so serious that the whole design of the tube has to be changed.) The materials used in the cathode or filament coating, for example, are not always too critical, provided appropriate steps in the subsequent processing can be specified. It is for this reason that controlled experiments in which two, three, and even more factors are deliberately changed simultaneously have become a standard procedure in our tube production department. We are not inferring that our tube manufacturing is now completely a science; but some definite advances have been made in the right direction. The techniques described here are not peculiar to our particular industry; they have important applications in all kinds of production operations, as well as in research and development work.

In the manufacture of one particular vacuum tube, difficulty had been encountered in the plant because of low power output. Experience led the production engineers to believe that increased contact potential would be accompanied by higher power output; consequently, it was decided to attempt the improvement of power output by varying the factors believed to control contact potential.

The particular design selected for this production experiment includes three different factors and two different levels of each factor. The three factors considered important by the production engineer for this experiment were the following:

(a) Plate temperature (P)
(b) Filament lighting (F)
(c) Electrical aging schedule (A).

On the basis of experience with these and similar tubes the production engineer selected two particular levels of each of these three factors; levels which he thought might give appreciably different results, yet which might reasonably be expected to produce usable tubes. These three factors were being controlled in the manufacturing operation at the time of this experiment, at levels which we will designate by P_1, F_1, and A_1. It was agreed to include these same levels in the production experiment which we were designing with other levels of each of these three factors which we will designate by P_2, F_2, and A_2.

There are eight possible combinations in any experiment which considers three factors at each of two levels, namely:

$P_1\ F_1\ A_1$ ←(Current production)	$P_2\ F_1\ A_1$
$P_1\ F_1\ A_2$	$P_2\ F_1\ A_2$
$P_1\ F_2\ A_1$	$P_2\ F_2\ A_1$
$P_1\ F_2\ A_2$	$P_2\ F_2\ A_2$

There are many experiments in which we include all eight combinations of factors. But in this particular one, we decided to use only a particular half of the possibilities, as described below and to include more tubes in each combination than would have been feasible if all eight combinations had been included. The design used was a Latin Square*, as in Figure 1.

By considering the inconveniences which the experiment would cause the manufacturing schedules and on the basis of the amount of variation experienced in preceding experiments, it was decided somewhat arbitrarily to use 12 different tubes with each of the four combinations of factors. (We have frequently used this same experiment design with only four or five tubes in each combination.) The design indicates that twelve

*Presented before the Metropolitan Section, ASQC, February, 1950.

*1. W. L. Gore, "The Role of Statistical Procedures in the Scientific Method."
2. K. A. Brownlee, "Industrial Experimentation."
3. H. A. Freeman, "Industrial Statistics," John Wiley & Son, N.Y., Chapter 2.

tubes were processed using each of the combinations:

I: $P_1\ F_1\ A_1$
II: $P_2\ F_1\ A_2$
III: $P_1\ F_2\ A_2$
IV: $P_2\ F_2\ A_1$

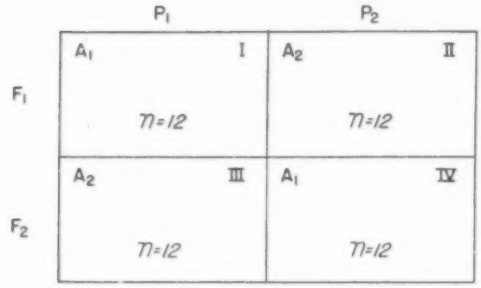

Figure 1—**A Latin Square Design**

With 12 tubes in each of the four test groups, it was possible to compare twice as many, or 24 for each of the main effects (P_1 vs P_2; F_1 vs F_2; A_1 vs A_2). When comparing P_1 vs P_2 the effect of the A factor has apparently been equalized in the experiment since half of the tubes in each of the two groups (in I and IV) were produced under condition A_1 and the other half under condition A_2 (in II and III). Similarly, the effect of F has been equalized in the experiment.

Every effort was made to keep all other contributing effects uniform in the process so that the reasons for any differences which might appear between tests of finished tubes could be attributed only to the factors of this experiment. For example, all tubes in the experiment were made from the same lots of components, by the same production line, and went through the same exhaust machines at approximately the same time.

After the tubes were sealed, the 48 were exhausted according to the design of the experiment with the two different plate temperatures, P; the filament lightings, F; and the aging schedules, A. The tubes were then tested electrically for contact potential and the readings in Table 1 were recorded.

TABLE I

	Test I	Test II	Test III	Test IV
	$P_1\ F_1\ A_1$	$P_2\ F_1\ A_2$	$P_1\ F_2\ A_2$	$P_2\ F_2\ A_1$
	−.20	+.28	−.08	−.22
	−.17	+.07	+.11	−.15
	−.18	+.17	−.05	−.10
	−.20	+.15	−.01	−.20
	−.17	+.16	−.07	−.17
	−.25	+.05	−.15	−.14
	−.14	+.15	+.04	−.12
	−.17	+.18	+.11	−.22
	−.15	+.07	−.06	−.21
	−.11	+.08	−.04	−.18
	−.19	+.08	−.05	−.21
	−.20	+.11	−.05	−.18
$\overline{X}$	−.1775	+.1292	−.0250	−.1750
R	.14	.23	.26	.12

A statistician might analyze these results by a technique called "analysis of variance." However, an analysis by control chart techniques is possible**, and indeed it is often preferable for different reasons, including the presentation of the results to the manufacturing personnel who are often familiar with them. This factor is of fundamental importance. A controlled experiment is of value to the production of a quality product *only* if the appropriate action, indicated by the experiment, is taken by the manufacturing personnel in the production operations.

An added argument for the control chart techniques is that the arithmetic is much less burdensome, less time-consuming, and far less conducive to error, and the implications for appropriate action are frequently more apparent.

Accordingly, the results of the four tests were plotted on an X, R control chart and the control limits calculated in the usual way. (Consecutive points on the graph have not been connected since there is no time factor involved in the experiment.) See Figure 2.

Since all four points on the range chart lie within the control limits, it appears that the variability of results from one combination of factors can be expected to be essentially equal to the variability from any other combination of factors. (Subsequent experiments may show that this conclusion is not true, of course.) Consequently, it is not unreasonable to estimate σ' for each combination of factors from the R of the four groups as follows:

$$\sigma' = \overline{R} / d_2 = .19 / 3.258 = .058.$$
$$(d_2 = 3.258 \text{ for } n = 12)$$

We will use this value of σ' as an estimate* of the variation in the groups to be compared. It appears, however, that the averages (X) of the four tests are significantly different, and the best results are obtained from condition II. (Incidentally, the current production schedule I is one of the two combinations giving the poorest quality.)

These results are very important. However, the graph does not tell the whole story. Inasmuch as not every combination was tested, it is necessary to find out which level of each factor is significantly higher. For example, it may very well be that P_2, A_2, and F_2 are the best levels, yet the P_2, A_2, F_2 combination was not included in the experiment and does not appear on the graph.

*If any border-line questions develop in subsequent analysis, it would be advisable to check this estimate of σ' by using the standard formula:

$$\sigma' = \sqrt{\Sigma (Xi - \overline{X})^2 / (n - 1)}.$$

These samples of 12 are larger than we prefer when we use the range; advice frequently given is not to use the range to estimate σ' when samples are larger than 10. Another method would be to break each group of 12 into 3 groups of 4 each and estimate σ' from the average range of these 12 groups of 4 each. In this experiment, the differences are so large that the use of the range is entirely adequate.

**Unpublished papers: "A Control Chart Analogue for Analysis of Variance," by T. A. Budne & P. Clifford; and "Statistics—A New Tool for the Planning and Analysis of Laboratory Experiments," by E. B. Ferrell, presented at the IRE, March, 1950.

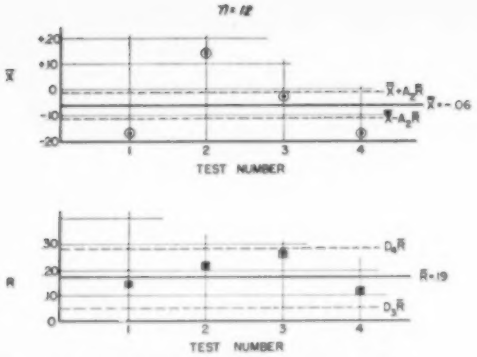

Figure 2—**Test Results in Control Chart Form**

From the way in which this experiment was designed it is possible to compare the effect of P_1 with the effect of P_2 by comparing the average of the 24 tubes in Tests I and III with the average of the 24 tubes in Tests II and IV. Similarly, the effects of F_1 and F_2 can be compared by averaging Tests I and II and comparing with the average of Tests III and IV; also the effects of A_1 with A_2 by averaging Tests I and IV and comparing with II and III. See Figure 3.

	P_1	P_2	
F_1	A_1 I −.1775 n=12	A_2 II +.1292 n=12	$\bar{F}_1$=−.0241 n=24
F_2	A_2 III −.0250 n=12	A_1 IV −.1750 n=12	$\bar{F}_2$=−.1000 n=24
$\bar{A}_2$=+.0521 n=24	$\bar{P}_1$=−.1013 n=24	$\bar{P}_2$=−.0229 n=24	$\bar{A}_1$=−.1763 n=24

Figure 3—**Test Results in Latin Square Form**

The difference between the two levels of each factor are:

$$P_1 = -.1013 \qquad F_1 = -.0241 \qquad A_1 = -.1763$$
$$P_2 = -.0229 \qquad F_2 = -.1000 \qquad A_2 = +.0521$$
$$P_1 - P_2 = .0784 \quad F_1 - F_2 = .0759 \quad A_1 - A_2 = .2284$$

In order to determine whether the difference between the two levels of $\bar{P}$ ($\bar{F}$ or $\bar{A}$) is statistically significant, the difference must be compared with the standard error of the difference* between the means, that is:

$$\sigma_{\bar{X}_1 \bar{X}_2} = \sqrt{(\sigma_1)^2/n_1 + (\sigma_2)^2/n_2}.$$

Since $\sigma_1 = \sigma_2 = \sigma'$ and $n_1 = n_2 = n$,

$$\sigma_{\bar{X}_1 \bar{X}_2} = \sqrt{2(\sigma')^2/n} = \sigma'\sqrt{2}/\sqrt{n}$$
$$= .058\sqrt{2}/\sqrt{24}$$
$$= .017.$$

*Croxton & Cowden, "Applied General Statistics," Prentice Hall, pgs. 329-330.

For the difference to be such that it would occur by chance less than 5 times in 100 samples of size n, it must be larger than $2\sigma_{\bar{X}_1 \bar{X}_2} = 2\sigma'\sqrt{2}/\sqrt{n}$. In this experiment, $2\sigma_{\bar{X}_1 \bar{X}_2} = .034$. In order that the difference be such as might occur by chance less than 3 times in 1000 samples of size 24, it must be larger than $3_{\bar{X}_1 \bar{X}_2} = .051$.

The three differences corresponding to the factors P, F, and A, are .0784, .0759, and .2284, respectively. In each case the difference is certainly larger than $3\sigma_{\bar{X}_1 \bar{X}_2}$ and the differences must be attributed either to the effects of the two levels being compared or to an interaction between the other two factors. However, it is impossible to test interactions by means of a Latin Square. If interaction is suspected, a complete factorial experiment must be tested using all 8 combinations referred to previously. (This test was performed at a later time.) The P_2 level is higher than P_1, the F_1 higher than F_2, and A_2 higher than A_1. Notice that these better levels P_2, F_1, and A_2 are those used in Test II, which resulted in the highest point on the control chart (Figure 2).

We have seen that these differences were significant from the statistical viewpoint. The production group asserted that these differences were also economically significant and they changed to test conditions II immediately. (Further testing was considered desirable and was actually performed at a later time.) Improvement in quality of tubes was highly satisfactory, however, as

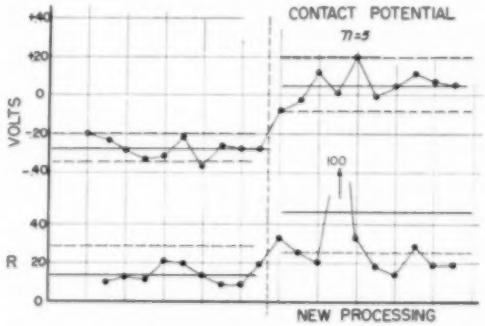

Figure 4—**Control Chart Record of New Processing on Contact Potential**

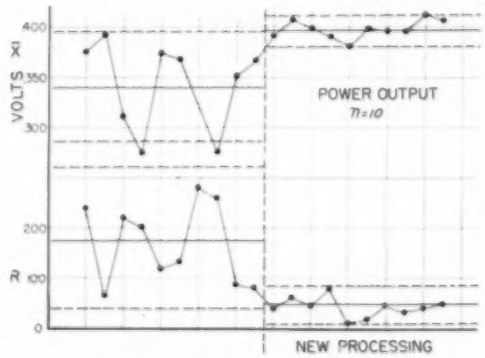

Figure 5—**Control Chart Record of New Processing on Power Output**

a result of this test alone. The process control chart showing production levels for power output and contact potential in the period immediately preceding the experiment (conditions P_1, F_1, A_1) and following the change to test conditions II (P_2, F_1, A_2), is shown in Figures 4 and 5.

It is quite obvious from Figures 4 and 5 that the change effected an increase in both contact potential and power output during regular production. From Figure 4 it may be seen that the average range of contact potential increased slightly. However, the production group needed the increase in power output and contact potential so badly that Test II conditions were put into effect even while further testing was proceeding. The reduced variation in power output was a welcome by-product. The reduction in scrapped tubes was immediate and substantial.

Additional experiments had to be performed with other levels and different factors. Some of these later experiments were complete factorials since there was reason to believe that interaction between these factors might be important.

Subsequent tests were run from time to time as occasion required. Other factors, besides the three considered in this discussion, affect the level of power output. Consequently, as some of these drift, it becomes expedient to run production experiments to find suitable manufacturing conditions.

The design discussed in this paper has proved to be a very versatile one for our purposes. It is, however, only one of several which we have found useful. But it is only rarely that we return to the use of "classical experimentation" where only one factor is allowed to vary.

In order for an experiment of this type to be successful, there must be cooperation between the Engineering and the Quality Control Departments. Full credit is due the Processing Engineer at the Sonotone Corporation, Tube Plant, Monte Edwards, whose engineering background and long experience in vacuum tube manufacture played an indispensable part in this experiment and others like it.

Practical Aids

ELLIS R. OTT, Editor

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The Error in Measurement

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INTRODUCTION

No measurement is entirely exact. No measuring process can translate a "measurable" characteristic of a product into its "true" numerical value. The difference of the recorded measurement (y) from the "true" numerical value (x) may be called the error (ε) of the measuring process. (Then $y = x + \varepsilon$).

This error of measurement is not produced by the measuring instrument alone. It is usually a result of three factors: (1) the measuring device; (2) the technician using this device; and (3) the conditions under which the measurements are made.

The importance of measurement errors is greater in some fields than in others. Where specifications are tight, where precise estimates of variability and quality of a product are required, or where it is essential that the error of measurement be reduced, we need to know a great deal about this error. It is especially important to have a method of estimating its average (μ_ε) and its standard deviation (σ_ε).

In this paper two techniques for separating the variability of the set of readings into its components are presented. The first is applicable with any sample size but it requires that two measurements be taken on each member of the sample with any one measurement process and that one additional measurement be taken on each member of the sample for each additional measuring process.

The second technique requires that one measurement be taken on each member of the sample with each of at least two measuring processes. For small samples the estimates obtained are not as reliable as those obtained by the first technique.

THE MEASUREMENT ERROR (ε)

All conditions remaining unchanged, repeated measurements on the same characteristic will yield a different value of ε for each measurement so that there exists a distribution of such ε's having a fixed mean, μ_ε, and a fixed standard deviation, σ_ε. We say that the smaller the magnitude of μ_ε, the greater is the "accuracy" of the measurement process, and the smaller the magnitude of σ_ε, the greater the "precision" of the measuring process. The magnitude of μ_ε is often referred to as the "bias" of the measuring process.

If the distribution of ε's, described above, is the same, regardless of the magnitude of x, then we say that x and ε are independent. The discussion which follows assumes that this independence exists. This is not always the case in some measuring processes, but the independence can often be brought about by taking a transformation (such as the logarithms) of the measurements.

A CONTROL CHART FOR MEASUREMENT ERROR

Whenever just one measurement process is involved, two sets of measurements such as y and y' on a relatively small sample provide sufficient information to

TABLE 1

y	y′	D = (y − y′)
2325	2300	25
2150	2075	75
2550	2600	— 50
2375	2400	— 25
1925	2025	—100
1850	1975	—125
1225	1325	—100
2125	2200	— 75
1700	1775	— 75
2100	2150	— 50
2200	2300	—100
1750	1800	— 50
2075	2075	0
2200	2200	0
2300	2325	— 25
2175	2300	—125
1725	1900	—175
1575	1675	—100
2325	2325	0
2400	2450	— 50
1825	1825	0
2100	2125	— 25
1600	1525	75
1850	1875	— 25
2350	2200	150
2200	2075	125
1825	1650	175
2050	1875	175
2325	2300	25
1950	1825	125
2125	2000	125
1700	1500	200
2250	2150	100
1975	1850	125
2300	2250	50
1875	1775	100
1875	1825	50
2175	2125	50
1975	1850	125
2025	1975	50
1975	2000	— 25
1825	1825	0
1550	1575	— 25
2225	2250	— 25
2150	2150	0
1950	1950	0
2025	2000	— 25
1700	1750	— 50
2050	2050	0
1950	1950	0

$\bar{D} = 10$

$\bar{R} = 37$ (where R is the range between successive pairs of D)

$\sigma_D = \bar{R}/d_2 = 33.8$; $3\sigma_D = 101.4$

UCL $= 0 + 101.4 = +101.4$

LCL $= 0 - 101.4 = -101.4$

separate the sources of error. This is possible provided the measuring process itself does not affect the characteristic being measured, and that the measurement errors are random. We could take many repeated measurements on a single item and compute σ_ε by conventional methods. Often, however, this is not truly representative of the measuring process under production conditions and may not characterize the variation which exists under the actual operating situations. Furthermore, we lose the opportunity to look for randomness of error as illustrated below.

A sample of 50 of a particular product was selected at random. (See Table 1).

y represents the measurements (in sequence of measurement) of a particular quality characteristic of each member of the sample. y′ represents measurements on the same sample, with the same measuring equipment and the same technician on a different day. D represents the algebraic difference between each pair of measurements. This control chart plots these differences. (See Figure 1). The $3\sigma_D$ limits are set by taking ranges of successive groups of two D's and estimating σ from $\bar{R}$. Even without limits, the cyclic pattern of points clearly indicates the presence of an assignable cause of variation. Since the samples were selected at random and since D is the difference of the two measurement errors alone, as shown in (a), any such pattern can only be caused by the measuring process itself. Indeed, it was caused by variations in the environmental conditions during measuring. The measurements had been made by using a piece of electronic equipment plugged into the power line of the plant. It was found that fluctuations in the line voltage had this cyclical effect on the measurements.

Obviously we cannot safely assume that the error of measurement in a given set of measurements is random. Not only may variation in environmental conditions affect measurements, but erratic behavior of either the instruments or of the technicians may also have a similar serious effect.

It is possible to determine the components of variation in a set of measurements only when we can believe that the measurement error is random. A control chart, as illustrated here, can give the assurance required.

A METHOD OF ESTIMATING THE COMPONENTS OF VARIATION

In the following example we consider two situations. In the first we have just one measuring process, A, and two independent sets of measurements y_A and y'_A have been made on each member of a sample of 36. (See Table 2). The differences, D_1, have been examined on a control chart and can be assumed to be random. $\sigma^2(y_A)$ and $\sigma^2(y'_A)$ were found by conventional methods of computation. R_1 represents the absolute value of D_1 and is therefore the range of two measurements on the same item.

The differences, D_1, are actually the differences between the two measurement errors alone since:

(a) $D_1 = y - y' = (x + \varepsilon) - (x + \varepsilon') = \varepsilon - \varepsilon'$.

Therefore, R_1 represents the range of two measurement errors when using measuring process A.

Applying standard control chart technique:

(b) $\sigma(\varepsilon_A) = \bar{R}_1/d_2 = 61.1/1.128 = 54.2$.

This procedure assumes that the "true" mean of the D_1's is zero. Since $\bar{D}_1 = 0$, we are safe in this assumption.

σ_x can now be estimated in the following manner:

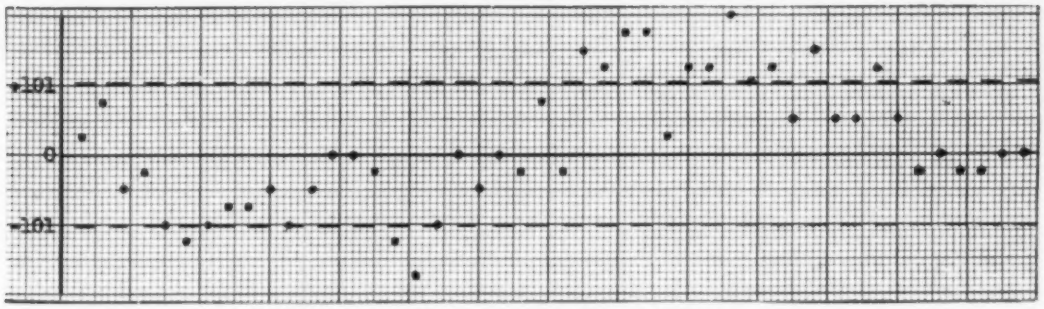

Figure 1—**Control Chart for Variable D of Table 1**

$\sigma_x^2 = \sigma_y^2 - \sigma_E^2$, since $y = x + \varepsilon$.

Therefore:

(c) $\sigma_x^2 = 83002 - (54.2)^2 = 80064$, using $\sigma^2(y_A)$ and $\sigma^2(\varepsilon_A)$,

(d) $\sigma_x^2 = 70436 - (54.2)^2 = 67798$, using $\sigma^2(y'_A)$ and $\sigma^2(\varepsilon_A)$.

The best estimate of σ_x^2 is the average of the two.

$\sigma_x^2 = (80064 + 67798)/2 = 73931$;

(e) $\sigma_x = 271.9$,

which is an estimate of the variability of the product measured.

Frequently, two measurement processes are available, one of which does not affect the measured characteristic of the sample, while the other is partially or completely destructive. A simple example would be the non-destructive measurement of thickness of plating by using the principle of magnetic fields as against destructive tests which require removal of plating with comparative measurements of thickness. A destructive test cannot be repeated on the same sample. If we have a destructive measuring process, B, we can apply this measuring process after the non-destructive measuring process, A, has been applied twice to the sample.

In Table 2, y_B represents a third independent set of measurements on the same sample of 36 taken by a second measuring process, B (which may or may not be destructive). D_2 is the difference between the y_A and y_B measurements on each member of the sample. As before, R_2 is the absolute value of this difference and again represents the range of two measurement errors alone.

As in (a), $D_2 = \varepsilon_A - \varepsilon_B$.

Since we are considering the standard deviation of a difference,

(h) $\sigma(D_2) = \sqrt{2} \cdot \overline{R}_2/d_2 = \sqrt{2}\,(79.9)/1.128 = 100.1$

$\sigma^2(D_2) = \sigma^2(\varepsilon_A - \varepsilon_B) = \sigma^2(\varepsilon_A) + \sigma^2(\varepsilon_B) = 10020.01$

squaring (b): $\sigma^2(\varepsilon_A) = 2937.64$

subtracting: $\sigma^2(\varepsilon_B) = 7082.37$

(i) $\sigma(\varepsilon_B) = 84.2$

As in (c) and (d),

(j) $\sigma_x^2 = \sigma^2(y_B) - \sigma^2(\varepsilon_B)$

$= 79653 - 7082 = 72571$.

The best estimate of σ_x^2 is now the average of (d), (e), and (j):

$\sigma_x^2 = (80064 + 67798 + 72571)/3 = 73478$;

(k) $\sigma_x = 271.1$.

Again, this procedure for finding $\sigma(D_2)$ was based on the assumption that the "true" mean of the D_2's $= 0$. Since $\overline{D}_2 = 7.6$ with $\sigma(D_2) = 100.1$, we had no reason to doubt this assumption. If there had been any doubt, then $\sigma(D_2)$ could have been found from the D_2 column by the conventional method of computation.

TABLE 2

		D_1		D_2
y_A	y'_A	$(y_A - y'_A)$	y_B	$(y_A - y_B)$
1575	1600	− 25	1650	− 75
2375	2375	0	2450	− 75
2150	2025	125	1925	225
1975	1900	75	1750	225
2025	2000	25	2100	− 75
2100	1950	−150	2025	75
1775	1750	25	1625	150
1675	1850	−175	1675	0
2425	2350	75	2325	100
1950	1975	− 25	2100	−150
2350	2350	0	2450	−100
1850	1875	− 25	1850	0
1675	1600	75	1600	75
2000	2000	0	2050	− 50
2250	2350	−100	2350	−100
1925	1875	50	1975	− 50
2575	2400	175	2500	75
1825	1825	0	1825	0
2050	1925	125	1925	125
1600	1650	− 50	1775	−175
2150	2100	50	2075	75
1800	1875	− 75	1850	− 50
2350	2400	− 50	2325	25
1550	1525	25	1625	− 75
1900	1875	25	1825	75
2075	2000	75	2025	50
2225	2175	50	2125	100
1925	1925	0	1775	150
1625	1675	− 50	1650	− 25
1775	1825	− 50	1900	−125
1350	1425	− 75	1400	− 50
1500	1475	25	1450	50
1800	1950	−150	1825	− 25
1650	1550	100	1650	0
1725	1825	−100	1725	0
1900	1900	0	2000	−100
$\sigma^2(y_A) = 83002$	$\sigma^2(y'_A) = 70436$	$D_1 = 0$	$\sigma^2(y_B) = 79653$	$D_2 = 7.6$
		$R_1 = 61.1$		$R_2 = 79.9$

A SECOND METHOD OF ESTIMATING COMPONENTS

Another method (1) of estimating σ_ε and σ_x requires one set of measurements on each member of the sample with each of at least two measuring processes. If we consider two measuring processes, A and B, then:

(l) $y_A = x + \varepsilon_A$

(m) $y_B = x + \varepsilon_B$

As in (a)

(n) $D_2 = y_A - y_B = \varepsilon_A - \varepsilon_B$;

from (l) $\sigma^2(y_A) = \sigma_x^2 + \sigma^2(\varepsilon_A)$;

from (m) $\sigma^2(y_B) = \sigma_x^2 + \sigma^2(\varepsilon_B)$;

hence:

(o) $\sigma^2(y_A) - \sigma^2(y_B) = \sigma^2(\varepsilon_A) - \sigma^2(\varepsilon_B)$;

from (n):

(p) $\sigma^2(D_2) = \sigma^2(\varepsilon_A - \varepsilon_B) = \sigma^2(\varepsilon_A + \sigma^2(\varepsilon_B)$.

We apply these relationships to the measurements y_A and y_B of Table 2, and using the estimates of variances already computed there:

$\sigma^2(y_A) - \sigma^2(y_B) = 83002 - 79653 = 3349$,

$\sigma^2(D_2) = 10028$.

Using (o) and (p):

(q) $\sigma^2(\varepsilon_A) - \sigma^2(\varepsilon_B) = 3349$

(r) $\sigma^2(\varepsilon_A) + \sigma^2(\varepsilon_B) = 10028$

$2\sigma^2(\varepsilon_A) = 13377$ by adding (q) and (r);

$\sigma^2(\varepsilon_A) = 6688$.

$\sigma^2(\varepsilon_B) = 10028 - 6688 = 3340$ from (r).

$\sigma_x^2 = \sigma^2(y_A) - \sigma^2(\varepsilon_A) = 83002 - 6688 = 76314$.

$\sigma(\varepsilon_A) = 81.8$ (54.2 by other method).

$\sigma(\varepsilon_B) = 57.8$ (84.2 by other method).

$\sigma_x = 275.2$ (271.1 by other method).

DISCUSSION OF BOTH TECHNIQUES

The differences in the estimates of variation obtained by the two methods can be explained in the following way: In the first technique, $\sigma^2(y_A)$ and $\sigma^2(y_B)$ did not enter into the computations. In the second technique, however, these two variances did enter into the computations. For small samples the sampling errors of such estimates can be large relative to $\sigma^2(\varepsilon_A)$ and $\sigma^2(\varepsilon_B)$. The result is that the sampling errors are reflected into the estimated values of $\sigma^2(\varepsilon_A)$ and $\sigma^2(\varepsilon_B)$. Hence, unless the sample is fairly large it cannot be expected that this latter technique will give accurate estimates of the measurement errors.

In the preceding discussions, A and B have been defined as different measuring processes. Since the measurement error is a result of three sources of error: the measuring instrument, the technician, and the environmental conditions, measuring process A may differ from measuring process B only to the extent that any one of the three factors given above has been changed. For example: We may use two different technicians with the same measuring equipment under identical conditions, calling the set of measurements of one technician, y_A, and the set of measurements for the other technicians, y_B. The resulting estimates, $\sigma(\varepsilon_A)$ and $\sigma(\varepsilon_B)$, would show the relative precision of the two technicians. Similarly, using the same technician and two different measuring instruments, we could find the relative precision of the two instruments. By making periodic repetitions of measurements, control charts plotting the differences of pairs of measurements provide estimates, as well as methods of control, of the errors of measurement.

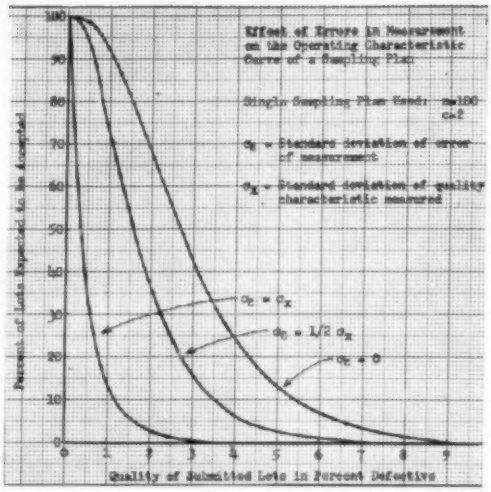
Effect of Error in Measurement on the Operating Characteristic Curve of a Sampling Plan
Single Sampling Plan Used: n=100 c=2
σ_ε = Standard deviation of error of measurement
σ_x = Standard deviation of quality characteristic measured
$\sigma_\varepsilon = \sigma_x$
$\sigma_\varepsilon = 1/2\ \sigma_x$
$\sigma_\varepsilon = 0$
Percent of Lots Expected to be Accepted
Quality of Submitted Lots in Percent Defective

Figure 2—**OC Curves for a Single Sampling Plan with Different Values of σ_ε**

THE EFFECT OF MEASUREMENT ERROR IN SAMPLING

It may be of some interest to note the effect on acceptance sampling operations when a substantial error in measurement is present. We consider a situation in which a one-side specification is applied to a measurable quality characteristic of a product and any member of a sample on the wrong side of this specification is considered a defective. Figure 2 shows the Operating Characteristic Curves of a Single Sampling Plan with a sample size of 100 and an acceptance number of 2 for cases of different relative values σ_ε. Obviously, for σ_ε greater than one half of σ_x, the sampling plan becomes much more stringent than for the case of $\sigma_\varepsilon = 0$. The selection of a particular sampling plan is usually determined by the characteristics of its Operating Characteristic Curve. Therefore, the choice of a sampling plan should be influenced by the magnitude of the error of measurement or the specification limit should be loosened to compensate for this error.

Reference

(1) Grubbs, F. E., "On Estimating Precision of Measuring Instruments and Product Variability", Journal of the American Statistical Association, June 1948, Vol. 43, pp. 243-264.

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. . . . AND THE LIVIN' IS EASY

Things are beginning to work out as we hoped on this project. Problems are coming in, and more important, so are solutions. If only this keeps up there will soon be time for me to read that book on executive techniques that rests on the shelf. We do have some work to do, trying to check up on the solutions submitted. Things look better, however. The long hard winter is over; can spring be far behind? Now for some problems.

Problem 4 (January 1952 IQC) asked about suggested procedures in "fitting" a line to a set of data that had been plotted on normal probability paper. I discussed this problem with Enoch Ferrell of the Bell Telephone Laboratories, and what follows is a summary of that discussion. Frankly, most of the ideas are Mr. Ferrell's, but I am responsible for any errors.

First, some comments on fitting lines on co-ordinate paper. To fit a straight line to any set of points, the classical way is to use least squares. This involves an amount of computation that any admirer of "quick and dirty" or "rough and ready" statistical methods likes to avoid. If the points are equally spaced along the X axis, a simple method is to split the data into halves, compute the center of gravity for each half, and draw a line through these two points. The center of gravity for the entire set will lie on this line, but the slope as determined by this method is not as reliable as that determined by least squares.

For this type of computation, the dispersion of the slope is a minimum if we use only the two end thirds of the data, discarding the middle third[1]. However, the minimum is a relatively flat one, particularly in the direction of using halves. Thus, if the middle point is odd, ignore it. Ignore a few more near the middle if it simplifies computation. Your estimate of position and slope have only a little greater dispersion than the least squares estimate.

Now, as to fitting a median line[2]. We suggest a very simple graphical method. The line is drawn so that half the points are above and half below, and so that the number of runs above and below the line is a maximum. From some empirical study we think that the dispersion of slope and position is about 25% greater for this method than for the conventional method. This would agree with what we know about the relative efficiency of the median and the mean, namely that the standard error of the median is 1.25 times the standard error of the mean.

Both of these methods have one important property: they soft-pedal wild shots. The median had this same advantage over the mean, and the range over the standard deviation. Most of us in quality control have learned that a large proportion of the data we get have some wild shots that need to be soft-pedalled.

Now, in fitting a line to data plotted on normal probability paper, we use a median line method. This is one place that you are much better off if you do not group the data. Up to 50 points, at least, you are better off plotting individual observations. Plot the individual points at $1/(n+1), 2/(n+1), \ldots, n/(n+1)$ on the percentage scale. Using these fractions means that you will find samples of 19, 24, 49, 99 very convenient.

Using a transparent ruler or a drafting triangle, draw the line so that half the points are above the line and half below, with the number

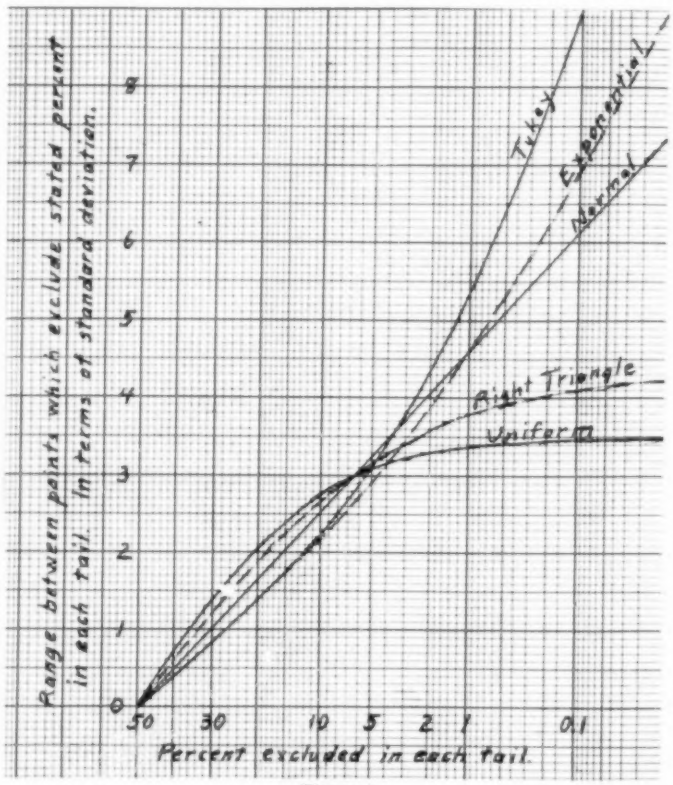

Figure 1

of runs above and below being a maximum. The value of x at the 50% point is the estimate of the median, and for normal distribution of the mean. The difference between the value of x at the 93% and 7% points divided by 2.95 is a good estimate of the standard deviation[3].

For large values of n the efficiency of this estimate is about .65. Moreover, varying the percentile points by 1 or 2 percent has very little effect on this efficiency (provided of course that the divisor is adjusted). This divisor is the z on a normal curve, such that mean ± z standard deviations includes the percent between the two selected percentage points. For 6.7%, z = 1.5 sigma, which is a convenient number to remember.

Sometimes data, when plotted in the manner stated, leave one a little doubtful as to whether the universe is normal, or may convince one that the universe definitely is not normal. Can any estimates be made of the mean or the median and the standard deviation?

The rather surprising answer is: Follow the same technique as for a normal distribution. The reason is that all distributions go through or near the points (6.7%, ± 1.5σ). These are the points which, for a normal distribution, give less dispersion in estimating sigma than any other two points. The accompanying graph (Figure 1) shows for five distributions the percentage of observations in the two tails beyond 1, 2, 3, ... 8 standard deviations. The normal distribution is of course a straight line. The uniform or rectangular distribution is a symmetric with short tails. The exponential, which has a very long tail, and the right triangular with a very short tail are of course skew distributions. Notice how close together the curves are at 6.7%, 1.5 sigma. For the symmetric distributions, the median is a good estimate of the mean. For the skew distributions this, of course, is incorrect.

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Problem 5—*Submitted by Gene Marning, Iowa Section.*

Our corporation makes it a practice to inspect all incoming shipments of heat-treated capscrews for Brinnell hardness. The vendors are rated as to their ability to produce parts in control and within our hardness specifications. The companies that are consistently in control are certified by the Quality Control Department and these vendors are given preference by the Purchasing Department.

Our problem is this: What is the correct method to use in computing control limits on Brinnell Hardness readings? The original data are expressed in bolt diameter readings with 5 mm. in each cell. Control limits can be computed using these readings, transposing them to hardness numbers only upon completion of the computations. Because of the unequal cell sizes in Brinnell hardness numbers, this method places the upper control limit at a greater distance from the mean than is the lower control limit.

If the hardness numbers themselves should be used in the computations, what are the mathematics involved in using a varying cell size?

Comment

The situation described here is a common one. Some quality characteristic X is measured. This measurement is transformed to a variable Y by means of a single-valued Y = f (X). Unless this relationship is linear, the control limits computed for X will not in general correspond to the control limits computed for Y.

Problem 6

Submitted by Harold Macormac, Metropolitan Section.

The use of the normal distribution to estimate the percent of items outside specification limits is well known. In the particular problem encountered, the specification was from .001 to .004, negative values being impossible. The most critical defects, known as "binds" occur between 0 and .001. When X and σ are computed it is usually found that X is only from one to two standard deviations above zero, indicating a skewed distribution. What method is recommended for estimating the percent of the items below .001?

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Book Reviews

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QUALITY CONTROL HANDBOOK
J. M. Juran; McGraw Hill Book Company, 1951; 800—viii pp.; $10.00. Review by Paul C. Clifford, State Teachers College, Montclair, N. J.

This is a monumental volume, both in size and scope. It is likely to be a revelation to any one whose concept of quality control has been established on the comparative flood of books concerned with the techniques of statistical method in quality control. Dr. Juran tries to place the statistical techniques in their proper position within the overall quality function. There is a consistent emphasis thoughout the book on the economic importance of quality control. Thus the viewpoint that quality control is concerned with establishing an overall program in which all departments participate recurs again and again throughout the book. To some extent this material on the management point of view is a restatement of that excellent earlier book by Dr. Juran, "Management of Inspection and Quality Control," published by Harper in 1945. The philosophy of that book has been brought up to date, elaborated and integrated with some of the newer developments of recent years.

Of the 800 pages, approximately one third are the writing of Dr. Juran. These are the chapters devoted to the economics, specification, acceptance, control and assurance of quality, plus a chapter on paper work in the quality function. In these chapters Dr. Juran has drawn on his own previous writings as well as on a vast store of material by other workers in the field. These chapters are replete with condensed case histories that give the reader the feeling that he has left the theory stage and is dealing with actual problems in the control of quality. To a great extent it is in these chapters that the first objective of the Handbook "to locate promptly the specific answers to actual problems as they arise in the day's work," is met.

The longest of these chapters is the one on control of quality. It is likely to be the one of most interest to many quality control operators. Dr. Juran defines control of quality as prevention of defects. He discusses two main tools for defect prevention: the Process Capability Chart and the Shewhart Control Chart. The first consists essentially of plotting a large number of individual pieces in the order of production to see whether they meet specification limits. The major claim for the process capability study is that it is readily understandable by shop personnel, whereas the control chart is "understandable only by technical personnel and therefore is (as yet) a laboratory tool." While this is probably an overstatement of the case, it indicates Dr. Juran's desire to strip away the statistical terminology that frequently frightens the novice in the field of quality control. There may be others who would disagree with Dr. Juran's definition of control of quality as defect prevention, especially in these days of steadily shrinking tolerances.

The importance of statistical method is recognized throughout the book. By far the largest chapter (146 pages) is that on "Statistical Methods in the Quality Function," by John W. Enell of New York University. This chapter takes up the usual material of descriptive statistics, various tests for significance of differences, control charts for average, range, percent defective, number of defects etc. There is an excellent presentation of acceptance sampling with a full discussion of the Dodge-Romig tables, the Columbia (Navy) tables, and the Military Standard Tables. In addition there is a good, brief treatment of correlation and analysis of variance. In addition to this chapter there are various places throughout the book where statistical techniques are discussed. Thus some relatively recent work by F. E. Grubbs on reliability of measurements is incorporated in the chapter on acceptance of quality. The short chapter by Dorian Shainin on vendor inspection is an excellent statement of his well known lot-plot plan of inspection. There is also a short chapter on "Quality Control in Textile Production" by John C. Hintermaier that discusses in detail the application of various statistical techniques to technological problems in the textile field. Thus there is essentially one third of the Handbook devoted to the techniques of statistics in the field of SQC.

In addition to the chapters mentioned, the largest section of the book is a chapter of 104 pages on "Organizing for Quality Control" by C. R. Scott, Jr. This is a thorough discussion of the problems of organizing an inspection department. Selection, training, and supervision of inspectors, and problems such as incentives for inspectors are analyzed. There is considerable attention paid to the attainment of quality-mindedness at all levels. The overall program of such companies as Bigelow-Sanford Carpet Company and Deere and Company are presented. The last part of the chapter discusses the problem of training in quality control, presenting quality control to management, and the introduction of quality control in a going plant. This last item is a ten-page discussion by Dorian Shainin of the particular problem of training in statistical techniques.

As stated in the preface of the Handbook, there are presented (in addition to the above universal material) some applications of principles to particular products and processes. The largest of these chapters is the one on "Quality Control in the Chemical Process Industries" by Charles A. Bicking. This is by far the most thorough analysis of the problems of control in the chemical industry that this reader has encountered. The problems are classified as: Unit Operations (Physical Changes) such as mixing, crystallization; Unit Operations (Semicontinuous) such as solvent extraction, sedimentation; Unit Operations (Continuous) such as gas absorption, molding and forming, heat transfer; Unit Processes (Chemical Changes) such as causticization, halogenation; Semicontinuous Processes such as polymerization; and Continuous Processes such as hy-

drogenation, hydration and hydrolysis, coupling, cracking, reduction etc. There are frequent sets of data that are analyzed with specific operating conclusions. The techniques of analysis are interesting ones, including multiple correlation and analysis of variance as well as the usual control charts. In addition there is an excellent bibliography on control in the chemical industries that lists over 100 references.

A second major chapter on specific applications is that on "Quality Control in Screw-Machine Operations" by L. A. Seder. This chapter discusses control by machine capability studies, the use of regular control charts, control charts allowing for tool wear, special control charts for individuals, for medians, and charts for graphing several sources of variation. There is also a section devoted to inspection procedures and control of tools and gages. Much of the material in this chapter is a restatement of the chapter on "Control of Quality." The emphasis is about even on the newer statistical tools for control and on the older routine procedures.

John G. Rutherford contributes a chapter on "Quality Control in Aircraft Manufacture." This is a detailed description of the procedures in use at one major aircraft company. The relations between the quality control department and other plant departments, and also between the quality control depariment and government or commercial agencies are examined. There follows a detailed discussion of the operation of different sections of the quality control department all the way from incoming inspection to flight inspection. Very little mention is made of any statistical analysis.

One additional chapter on specific applications is contributed by members of Sylvania Electric Products, "Quality Control of Electron Tubes." This relatively short chapter gives a detailed description of the procedures in use at Sylvania from initial specification of quality to life and design tests and investigation of quality complaints.

One chapter not yet mentioned is by International Business Machine Corporation on the "Applications of Electric Accounting Machines to Quality Control." The use of I.B.M. cards to help analyze final parts inspection either 100% or by sampling, to establish scrap control, and to analyze quality in final assembly is given in detail.

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It is a difficult job to review this volume. Dr. Juran's views on quality control are already familiar, in general, to most of the members of ASQC. One cannot help being impressed by the magnitude of the task Dr. Juran has set for himself, and which he has in the main, accomplished. But it is an open question whether one person or group of persons could accomplish what is set for the objective. Looking over the whole shelf of books that have appeared in recent years, plus the list of technical articles, plus the developments in the field of statistics itself, this reviewer tends to feel that the applications of quality control have become so vast and diverse that they almost defy inclusion in any book. Dr. Juran states in the preface, "It is the intention of the editor, in revisions of the handbook, to expand greatly the number of sections dealing with applications to products and processes." This is a herculean task and one can only admire the editor's courage in tackling such a project.

As is obvious from the roster of names, there has been considerable effort to secure authoritative information on each application covered. This in itself causes some difficulty. There is considerable duplication between chapters and sometimes contradiction between authorities. The fundamental reasoning behind the control chart for averages and ranges is explained in several different chapters. Each chapter is an excellent treatise if considered separately, but not quite so satisfactory when considered as part of the whole book. Thus, in addition to the chapter on vendor inspection, there are some thirteen other places in the text where various aspects of vendor inspection are discussed, not counting large sections devoted to different acceptance sampling tables and other statistical techniques associated with vendor inspection. From the point of view of a handbook for ready reference, this tends to mean that the book should almost be read throughout, before it can be easily used as a reference. To compensate for this there is a thirty page index that does enable one familiar with the text to find topics quickly.

Pointing out the book's few shortcomings makes a reviewer feel like a Monday morning quarterback, especially when he himself has not written a book, and so is safe from having to "put up or shut up." This book will probably become one of the standard references in the field, and it is certainly indispensable for anyone actively concerned with quality control. It ought to be read through and consulted by executives, engineers, supervisors and those in training to be executives and supervisors.

I am more doubtful of the value of the book for the second and third objectives stated in the preface. The preface states that it has been designed for training courses in industry and as a texbook for college courses in quality control. The organization of the book, and its very magnitude, make it somewhat advanced for anyone without active experience in industry. It would seem to be well suited for advanced courses or conferences for quality control executives who have had some previous acquaintance with the fundamental concepts of SQC.

STATISTICAL METHODS FOR CHEMISTS

W. J. Youden, John Wiley & Sons, 1951, ix + 126 pp., $3.00. Review by T. R. Bainbridge, Tennessee Eastman Company, Kingsport, Tenn.

In his preface, Dr. Youden states that the purpose of the book "is to make available to the scientist the modern statistical system of units for expressing scientific conclusions." The book is opened by an excellent discussion of what the statistician has to offer the experimenter. Dr. Youden very aptly foresees the usual objections to the use of statistics and answers them well.

A conscious effort was made to shorten the introductory material because of the feeling that most chemists already know a great deal about data that is not known to the usual student of statistics. However, some discussions have been so shortened as to be somewhat vague. For this reason I would recommend that a beginner familiarize himself with basic concepts before using this text.

Of particular interest to the chemist will be the discussion of statistics of the straight line. Dr. Youden does not discuss correlation in the usual sense but illustrates how the highly correlated results of different chemical analyses may be studied to compare observed slopes and intercepts to theoretical slopes and intercepts.

There are also excellent sections on cautions which must be observed in using analysis of variance, on interpretation and presentation of data, on the concept of interaction, and on the importance of random arrangements.

The development of the analysis of variance does not include as straightforward a system of classifying and of calculating tables of variance as the "cook book" style of Brownlee. For a man who is primarily a chemist rather than a statistician, this might be considered a serious fault. In addition, Dr. Youden does not discuss pooling of insignificant mean squares with the mean squares for the residual or for an interaction. He does infer that this may be done, but gives no rules for doing so. He states on page 70 that interactions of more than three factors are of secondary interest; but, on page 69, recommends replication of a three-factor experiment to provide an estimate of error. To be consistent, it would appear that he should have recommended the addition of a fourth factor at two levels, to give as valid an estimate of error and a look at an additional factor at no more cost than replication.

In his discussion of Latin squares, Dr. Youden gives an example of replicated Latin squares, but his explanations of the necessary calculations are sketchy.

The chapter on "Experiments with Several Factors" is a survey of methods only, and a novice could not use it without the supplementary material referred to.

The tables provided include tables for t, tables for F at the 1% and 5% levels, and tables of squares. The substitution of tables of F at additional levels for the tables of squares would have provided the average chemist with much more useful information that would not be available to him in standard handbooks.

Chapter headings are "Precision and Accuracy", "The Measurement of Precision", "The Comparison of Averages", "The Resolution of Errors", "Statistics of the Straight Line", "The Analysis of Variance", "Interaction Between Factors", "Requirements for Data", "Arrangements for Improving Precision," and "Experiments with Several Factors."

This is an adequate text and if used in conjunction with the *A.S.T.M. Manual on the Quality Control of Materials* and a few additional tables, would constitute a very workable, relatively complete, and quite inexpensive library for the chemist.

Bibliography

JOSEPH MOVSHIN, Editor

Assisted by the Editorial Committee, St. Louis Section, ASQC

On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to: Mr. Joseph Movshin, 9220 Old Bonhomme Road, St. Louis 24, Mo.

APPLICATION—AUTOMOTIVE INDUSTRY

THE HOW AND WHY OF S.Q.C., J. C. Knapp, Superintendent of Quality Control, Ford Motor Co. of Canada, Ltd.

(Plant Administration, August 1951, p. 25; September 1951, p. 35; October 1951, p. 46)

The first article in this series presents a brief history of S.Q.C. and a discussion of the frequency distribution. This is followed by an introduction to the X and R chart.

The second continues with case history discussions of the use of the average and range charts. Illustrated with numerous charts.

The last article in the series introduces sampling plans. Several interesting frequency distribution charts of assembly components are given and discussed.

APPLICATION—METAL WORKING

QUALITY CONTROL OF JOB LOTS, Dorian Shainin, Chief Inspector, Hamilton Standard Division, United Aircraft Corporation. (Part 1. The Tool Engineer, v. 28, n. 1, Jan. 1952, p. 35) (Part 2. The Tool Engineer, v. 28, n. 2, Feb. 1952, p. 47)

After discussing briefly the economics of quality control, Mr. Shainin presents several statistical tools for control of job lot quantities. One of these, the Reset-Run card, provides a means of accumulating the variations from a zero setting for successive pieces until a point enters either the Reset or the Run portion of the preprinted card.

Other tools described are the Sum and Range control chart and a modification of the well known Lot Plot Method, suitable for small lots and called the Continuous Lot Plot.

STATISTICAL QUALITY CONTROL AT THE UNIVERSAL WIRE SPRING CO., W. H. Neely, President, Universal Wire Spring Co., Bedford, Ohio. (Part I. Tooling and Production, v. 17, n. 10, Jan. 1952, p. 52) (Part II. Tooling and Production, v. 17, n. 11, Feb. 1952, p. 106)

After a description of this company that produces seat springs for the automotive, furniture, and aircraft industries, the quality controls of these products are discussed. Average and range charts are used, as are continuous summary charts.

In Part II, np charts are used to record the results of gauging of spring angle of bend and other characteristics. Again, summaries of these are used effectively. Management's benefits and satisfactions are noted.

INCREASE MACHINE CAPACITY WITH CONTROL CHARTS, Joseph Manuele, Director, Headquarters Quality Control Department, Westinghouse Electric Corp.

(American Machinist, v. 96, n. 4, Feb. 18, 1952, p. 131)

The author points to four factors affecting machine capacity: uniformity of materials, condition of machine, adequacy and condition of cutting tools, and operator's method of running machine, particularly the frequency of adjustments.

Increases in production of as much as 30% have been obtained by use of control charts to determine when tool adjustments are necessary. Charts for individuals rather than averages are recommended for these investigations.

APPLICATION—MISCELLANEOUS

STATISTICAL AIDS FOR ACCURATE STANDARD DATA, Gerald Nadler, Washington University.

(Advanced Management, v. 16, n. 11, Nov. 1951, p. 11)

This article presents an application of the $\bar{X}$ and R chart as a check for consistency of standard time data for a series of time studies. A measure of reliability in terms of the percent range (of the average) is also charted.

STATISTICAL QUALITY CONTROL SAVES TIME, J. M. Mannion, Chief Inspector, Northrop Aircraft, Inc.

(Modern Machine Shop, v. 24, n. 8, Jan. 1952, p. 96)

The author describes the part that Statistical Quality Control plays in improvement of quality through tooling, fabrication, subassembly and assembly operations at Northrop. Illustrations of some of their forms are included.

GLOSS MEASUREMENT OF PAPERS—THE EFFECT OF LUMINANCE FACTOR, V. G. W. Harrison and S. R. C. Poulter, Printing, Packaging and Allied Trades Research Assn., Leatherhead, Surrey, England.

(British Journal of Applied Physics, v. 2, n. 4, Apr. 1951, p. 92)

This paper presents a method of relative measurement of paper gloss. This rating is based upon the ranking of samples of selected papers by many individuals. The distribution of ratings for the various papers are analyzed and used to establish psychological gloss scales. Experiments in weight grading check these results.

STATISTICAL ANALYSIS AIDS QUALITY CONTROL, P. C. White and W. B. Traver.

(The Oil and Gas Journal, v. 50, n. 12, July 26, 1951, p. 250)

The author presents Statistical Quality Control as a guide to the interpretation of refining measuring techniques. Illustrated are the average and range chart used to control filling weight of

motor oil; the control chart for thermal cracking run lengths; and the control chart for shutdown frequencies. The design of experiments, evaluation of new instrumentation, and motor oil mileage tests using analysis of variance are discussed.

MANAGEMENT AND PERSONNEL

STATISTICAL CONTROL SAVE I-H $10 MILLION, M. J. Graham, Director of Manufacturing, International Harvester Co.

(American Machinist, v. 96, n. 4, March 3, 1952, p. 153)

The story of how reductions in rework and scrap-cost ratios at the various plants of the International Harvester Co. during the past four years brought about cost improvements totaling $10,000,000. Illustrated with charts and a picture.

MISCELLANEOUS

STATISTICS, Warren Weaver, Director for the Division of Natural Sciences and Agriculture in the Rockefeller Foundation.

(Scientific American, v. 186, n. 1, Jan. 1952, p. 60)

A non-mathematical report on statistical methods, defined as the science and art of uncertain inference. It discusses such topics as samples and populations, precision of estimates, Bayes theorem, frequency distributions, confidence coefficients and others.

QUALITY CONTROL PANEL (QUESTIONS AND ANSWERS), John Santi, Marquette University.

(SAE JOURNAL, v. 60, n. 2, February 1952, p. 18)

The answer to some eighteen questions of a general nature asked of the Quality Control Panel at the SAE National Tractor Meeting last September 10.

SAMPLING PLANS & RELATED TOPICS

PROBLEMS IN CLASSIFYING DEFECTS, Norman H. Sherman, Jr., Quality Control Division, Air Materiel Command, Wright-Patterson Air Force Base.

(Technical Data Digest, v. 17, n. 2, Feb. 1952, p. 16)

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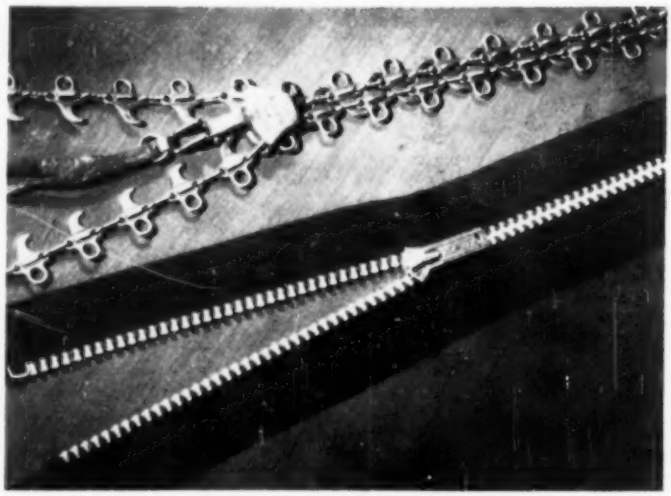

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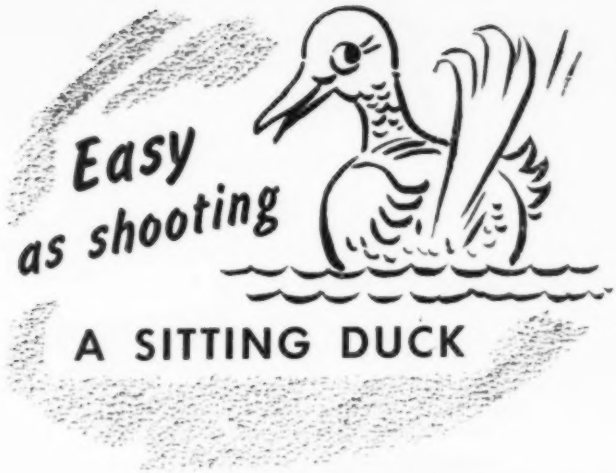

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An excellent detailed discussion of the classification of defects for sampling plans. Particular emphasis is on the Air Force approach and the MIL-STD-105A classification. The logic of the approach used, however, can be extended as a working approach in other situations.

THEORY & APPLICATION—GENERAL

FUNDAMENTALS OF A TEST METHOD, Gilbert L. Peakes, Bakelite Co., Bound Brook, N. J. (ASTM Bulletin, n. 179, Jan. 1952, p. 57)

Mr. Peakes discusses the prerequisites to the usual statistical tests, etc., of the results of a test method. That is the choice of standard conditions or precautions necessary for consistent results. This first step is described as "Experimentation to integrate a sequence of acts involving product, test apparatus, reagents, etc., so that a numerical measure of product quality is obtained." Analysis of variance is used to strike an economical balance between product and test method variance.

STATISTICS

THE DISTRIBUTION OF THE QUOTIENT OF RANGES IN SAMPLES FROM A RECTANGULAR POPULATION, Paul R. Rider, Washington University and Flight Research Laboratory (USAF).
(Journal of the American Statistical Association, v. 46, Dec. 1951, p. 502)

In this paper Dr. Rider develops the distribution of the quotient (or ratio) of two ranges from a rectangular population. From tables of the probability of occurrence of various values of this ratio, a test for the hypothesis that two samples came from the same rectangular population can be made. Tables of 10%, 5% and 1% points for samples of from 2 through 10 are given.

THE DISTRIBUTION OF THE RANGE IN SAMPLES FROM A DISCRETE RECTANGULAR POPULATION, Paul R. Rider, Washington University and Flight Research Laboratory (USAF).
(Journal of the American Statistical Association, v. 46, Sept. 1951, p. 375)

From the distribution of the range from discrete rectangular populations, the probability of obtaining a sample range equal to the population range is found. Table of this function is given.

EFFECT OF NON-NORMALITY ON THE POWER FUNCTION OF THE F-TEST IN THE ANALYSIS OF VARIANCE, E. N. David and N. L. Johnson.
(Biometrika, v. 38, June 1951, p. 43)

ALTERNATIVE APPROACHES TO THE THEORY OF CHOICE IN RISK-TAKING SITUATIONS, K. J. Arrow.
(Econometrica, v. 19, Oct. 1951, p. 404)

ON SETS OF PROBABILITY LAWS AND THEIR LIMIT ELEMENTS, M. Loeve.
(California University Statistical Service, v. 1, n. 5, 1950, p. 53)

Forthcoming Courses in Statistical Quality Control

UNIVERSITY OF COLORADO

A ten-day course in basic SQC will be offered by the College of Engineering (including the Departments of Applied Mathematics and Mechanical Engineering) at the University of Colorado, Boulder, Colorado, June 17-27, 1952, inclusive.

This will be a basic course covering control charts and acceptance sampling and other statistical techniques useful to industry and business. The course will be intensive, mathematically non-technical, and practical.

Tuition is $100, which includes books and supplies. Living accommodations will be available in modern University housing facilities, including meals, or rooms and cabins may be obtained in hotels and tourist camps off the campus.

Further inquiries and applications should be addressed to Professor John F. Wagner, Department of Applied Mathematics, University of Colorado, Boulder, Colorado.

PURDUE UNIVERSITY

An eight-day Advanced Course in Statistical Quality Control will be offered by Purdue University June 4-12, 1952, inclusive. This course is intended to meet the needs for additional training of men and women who have had some previous instruction or practical experience in the subject.

Topics to be offered are: review and background of control charts, significance of differences, principles of acceptance sampling, sequential analysis (attributes and measurements), linear and multiple correlation, analysis of variance, tolerances of fitting parts, chi-square, and use of calculating machines.

Prerequisites are a first course or its equivalent. Emphasis will be on applications, and all techniques will be explained as simply as possible.

Tuition is $100. For additional information, write to Professor Irving W. Burr, Statistical Laboratory, Purdue University, Lafayette, Indiana.

THIRD "HORSE'S MOUTH" COURSE

The New England Sections of ASQC are again cooperating with the University of Connecticut to present a third annual "horse's mouth" SQC Institute at Storrs, Connecticut, August 3-15, 1952.

The unique feature of this program is the diversity and prominence of the lecturers. The student is brought face to face with leaders in the quality control field who are actually applying modern quality control methods to obtain day-to-day results. The sponsors are aiming this course at those who want to look at quality control from the broad viewpoint of specific application.

Material will include detailed descriptions of the most recently developed practical techniques such as Binomial Probability Paper, Lot Plot, Continuous Lot Plot, VOSP, and Reset-Run Cards.

Tuition is $150 per person which includes room, board, and text and class material. For further information or registration, write to Mr. R. M. Story, Jr., Coordinator, SQC Institute, Box U-41, University of Connecticut, Storrs, Conn.

UNIVERSITY OF MICHIGAN

The University of Michigan has scheduled the fifth annual repetition of its ten-day intensive course in statistical quality control for August 18-28, 1952 on the campus in Ann Arbor. This is a first course for executives and supervisory personnel, practical and mathematically non-technical. It includes the standard control charts and sampling acceptance plans together with other basic techniques. Instruction includes lectures, demonstrations, practice sessions, and conferences. The fee will be $100.

Please address inquiries to the course director, Professor C. C. Craig, 106 Rac'tham Bldg., Ann Arbor, Michigan.

8TH SQC COURSE FOR THE CHEMICAL INDUSTRIES

An eight-day intensive training course in Quality Control for the Chemical Industries will be offered by the Rochester Institute of Technology at Rochester, New York, October 15-23, 1952. In contrast to courses which usually emphasize mechanical and metal cutting operations, the content of this program is devoted exclusively to the control problems of the chemical and allied process industries.

The course is particularly designed for those responsible for controlling product either in the analytical laboratory or directly in the manufacturing process. Emphasis will be placed on the practical application of quality control in these areas. Instruction will cover basic statistical control and sampling methods as well as many of the advanced techniques such as design of experiments, correlation, and analysis of variance. Companies engaged in research and development work, or those having a continuous or batch lot type of production process will find the program of particular value.

The tuition of $100 per person includes books and supplies. Room accommodations will be available at the Hotel Rochester. Further inquiries should be addressed to the course coordinator, Alfred L. Davis, Rochester Institute of Technology, Rochester 8, N. Y.

STATE UNIVERSITY OF IOWA

A ten-day intensive training course in Quality Control by Statistical Methods will be offered by the State University of Iowa at Iowa City, Oct. 7-17, 1952. This will be an introductory course which will follow the same general pattern of previous basic courses.

Instruction will be by lecture, demonstration, laboratory work, and evening question and problem discussion sessions, with the emphasis on practical interpretation throughout.

The tuition of $100 per person includes all necessary instructional materials. Room accommodations will be available at the Jefferson Hotel in Iowa City. Make room reservations directly with the hotel.

Further inquiries concerning this course should be addressed to Professor Lloyd A. Knowler, Chairman, Department of Mathematics, The State University of Iowa, Iowa City, Iowa.

From the Scrap Box

Mr. H. G. Thompson, Director of Quality Control at The Master Electric Company in Dayton, Ohio, submits the following views on the general subject of "the science of quality control":

The writer is one of the "founding rebels" of our Society who has long thought that the statistical tools of our profession are being overemphasized at the expense of many other very necessary and helpful facets in the broad field of controlling quality.

Statistical procedures are fine tools, which have served more than any other to focus world-wide attention and interest on the quality function. However, the honeymoon is about over, and the members and sections of our Society are going to have to round out their thinking and come forth with good papers, discussions and training programs on the many other essential phases of controlling quality. Lacking this, neither the members nor the Society will grow in stature and recognition.

What are these other aspects of a complete quality control program? The basic branches of a good system of insuring quality are economics, specifications, organization, procedures and controls, measuring equipment, personnel and quality assurance. Dr. J. M. Juran does an excellent job of covering these in his "Quality Control Handbook" just recently published. We are limited here to only a brief discussion.

There is much room for advancement in studies of the economics of controlling quality. Far too little analysis is given to this subject largely because attention has not been focused upon it. Numerous examples of this exist in all industries. In the automotive field the older members should vividly recall the several cars that were economic failures because of extremely high quality standards with their attendant high costs, as contrasted to the Ford (Model T) which was a huge economic success because of adherence to *minimum acceptable* quality. To those who say that this example is beyond the scope of the ordinary quality control group, it should be stated that unless the quality control supervisor is capable of pointing the way in such decisions he is not a true professional in his field.

Hand in hand with the economics of quality control should go a critical study of specifications, as well as of organization. Some of the most profitable companies have the simplest specifications and the most streamlined organizations. The common tendency is to accept specifications written with too little thought instead of actual functional requirements. Then the parallel tendency is to over-organize to control more and more detailed elements whose effect on the final product is often questionable.

The above three fundamental subjects deserve much more consideration than our members have given them.

There are many ways of controlling quality other than statistically. Usually these procedures are functioning simultaneously with the statistical in an established organization even though one may be largely unaware of them. They are important because a quality control program set up without their support will not be successful. There were notable examples of this during World War II. Controls, in the field of quality, aid in prevention of recurring defects. Statistical tools may be used quite profitably, but in addition there must also be (1) a basic philosophy of quality, in the proper degree, indoctrinated into the organization; (2) a knowledge of the process, equipment and materials; (3) proper measurement or evaluation of the points in question; (4) confidence of management and or the manufacturing supervision in the ability and fairness of the quality control personnel. Too often these points are crowded out of our discussions by formulae and charts.

One successful company has a Quality Club which meets each week at a Wednesday noon luncheon, paid for by the company. About two-thirds of the hour, or longer if necessary, is spent discussing defects which have been uncovered by "spot" inspections of their product picked at random when ready to ship. Field complaints are similarly discussed. Attending this meeting are top men from all divisions, including the president and vice-presidents of manufacturing, sales and engineering. One of these top men presides at the meeting. Reports to be discussed have been sent out several days in advance of the meeting. The man in charge of the department responsible for the defect has to explain before the group why it occurred and what is being done to prevent a reoccurrence. If design, specifications, processing, purchasing, sales or some other phase is contributory, the responsible people are there to enter into the discussion. A line of action is decided upon immediately, and, if necessary, checked on the following week. This company, by placing emphasis for quality exactly where it belongs, without delay, has a small quality control group, and coincidentally has the best profit history in its industry.

Without proper gauges, fixtures, measuring tools and equipment the whole field of quality control would collapse. Yet this subject is largely taken for granted or lightly treated in papers and training programs. Too many quality control engineers are

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painfully uninformed in fundamental measuring techniques in their own industry.

A few papers have appeared on personnel but, here again, there is a large void of information (in our own Society) on such things as aptitude and attitude studies, on eyesight tests, on check inspections, on payment plans including the pros and cons of incentives or bonuses, and many others.

In the field of quality assurance and reporting to management, statistical methods are rightfully predominant, and are a comparatively newer phase in the quality control field. These subjects have been fairly well covered in conferences and papers, but new ideas or variations would be welcomed.

Let's bring these other aspects of the quality function into our meetings to a greater extent; show the complete picture; bring about more discussion and training on the neglected phases; and make ours a well-rounded society. We will then be able to hold many more of the "practical" members who join our Society on the basis of its name and constitution and soon drop out because we haven't lived up to our stated objectives.

The following historical account of the working relationship between the Tennessee Section, ASQC, and the University of Tennessee is submitted with the idea that perhaps other Sections may find these same procedures useful.

The Tennessee Section from its inception in 1947 has worked closely with the University of Tennessee. The first preliminary meeting was held under the auspices of the University Extension Division with representatives of the College of Business Administration, Mathematics Department and the new Department of Industrial Engineering. One result was to stimulate the University to provide more instruction in statistical methods.

Close collaboration has been carried on with the Extension Division of the University which was encouraged to offer courses at various levels in quality control and statistical methods. In turn, the University has called upon members of the Tennessee Section to teach these courses throughout the state.

A conference on quality control was held on the University of Tennessee campus in the spring of 1950, jointly sponsored by the Tennessee Section of ASQC and the Departments of Statistics and Industrial Engineering of the University through coordination of the Extension Division's office of conferences. Since then the Coordinator of Conferences of the University and area representatives of the Extension Division have collaborated and helped make all arrangements for ASQC meetings in the State of Tennessee. Expenses and proceeds are shared. The Tennessee Section Chairman appoints a Program Chairman and an Arrangements Chairman in each community holding a meeting. The Arrangements Chairman works closely with the area supervisor of the Extension Division in all physical arrangements. The Office of the Coordinator of Conferences takes care of mailing all announcements, two or more for each meeting. These go not only to members of the ASQC, but to all potentially interested companies in the state, using mailing lists available in the Office of the Coordinator.

This help on the mechanics of conference planning and arrangements is of great value since members of the society are all busy people and each meeting involves a tremendous amount of detail work. The appropriateness of this close collaboration was discussed at a recent membership meeting and fully endorsed. The University attaches no strings to its contribution; in turn its program of Extension courses in Industrial Engineering and Management topics is advanced since each meeting in various Tennessee cities stimulates attendance in courses in SQC.

ASQC members and meetings have developed considerable interest in the state among manufacturers in trying out quality control. They turn to the University for graduates with training in this field to fill their needs.

Various by-products of this collaboration are showing up, such as growing interest at the University in such subjects as instrumentation, gaging and measurements, and analysis of experimental data by statistical means. Advice of the Tennessee Section has been sought on University course offerings and course content.

This close collaboration between local sections and neighboring universities thus has many advantages, few or no disadvantages, and seems to be a logical, natural, and appropriate way to advance the use of industrial quality control. At least that is what the experience of the Tenressee Section working with the University of Tennessee indicates.

Management's Corner

J. M. JURAN, Editor

Correspondence is invited on potential contributions or problems appropriate for discussion in this department. Address your suggestions to:

J. M. JURAN
195 Beech Street
Tuckahoe, N.Y.

This department has just finished participating in the last of three, 3-day seminars in Quality Control for 15 industrial executives,[1] each from a different company. The interests of these men were necessarily at the managerial level, and most of the time was devoted to managerial problems rather than to technical problems of product or process.

Of interest to members of ASQC is the agenda adopted by these men. They stated their problems at the outset, and then voted on a ballot to develop an order of priorities for discussion. The list of problems receiving the most emphasis included:

- Developing quality-mindedness
- Organization for quality control in the company
- Developing quality specifications
- Standards for visual (or other sensory) characteristics
- Executive reports on quality
- Effect of piece-work incentives on quality
- Process capability
- Control of outgoing quality
- Quality control for new products
- Control of accuracy of measuring instruments
- Reduction of scrap and rework
- Foreman training in quality control
- Training of inspectors

1. One was works manager, three others were chief engineers, and the rest were quality control managers (or related title).

Quality relations with customers
Purchasing on the basis of quality
Problems posed when inspectors report to production supervisors
Problems of multiple plant operation
Sampling inspection problems
Rating outgoing quality
Coping with tradition in the company
Control of small lot production
Control of "hand" operations
Control chart problems
Dealing with government inspectors
Effect of "corner cutting" to meet cost estimates

Naturally, 15 other executives would have shifted emphasis somewhat, depending on size of companies, kind of product, etc. But the list of topics is still indicative of the breadth of the problems faced by those industrial executives who preside over the quality function in their companies.

The seminar, under the sponsorship of the American Management Association, met for three days in September 1951, again for three days in December 1951, and a third time in March 1952. The role of the discussion leaders[2] was to facilitate exchange of information and ideas among the executives, rather than to lecture to them. The result was, by unanimous opinion, a mutual exchange of the highest value.

The months elapsed between meetings permitted members of the seminar to take on actual projects in their own companies and to report the results back to the group.

Several executives studied organization for quality in their companies[3] and brought most interesting data back to the group. Some of these men were faced currently with a considerable problem in organization. With the aid of the seminar they came much closer to practical solution.

Several companies faced serious problems in visual standards for quality. Some excellent work was done by seminar members in measuring customer sensitivity, in measuring competitors' quality, in measuring inspector reproducibility, and in other phases of the problem.

There was great interest in the problem of reporting various aspects of quality—cost of defects, level of outgoing quality, cost of inspection, etc. The manner of putting on a campaign for quality-mindedness likewise commanded keen interest. The nine days were fully occupied with discussion of these and the other problems.

This seminar suggests an excellent research study for those who are seeking an answer to the question "What is Quality Control?"

What are the quality problems as seen by the executives? A listing of these, with some idea of the order of importance, would be of great aid to the membership and the leadership in ASQC.

2. William H. Smith of Ford Motor Co., and the writer.

3. See in this connection, Industrial Quality Control, January 1952, Management's Corner, pp. 42-43.

QUALITY CONTROL SAVES A GRASS CROP

Moving down the windrow, the New Holland Field Forage Harvester picks up grass, chops it and blows the chopped material into trailing wagon in a steady, automatic action.

Time . . . measured in minutes . . . is all-important when farmers are getting in their grass crops. Too long a lay in the windrow can over-wilt a crop, causing the loss of valuable proteins and vitamins. Or failure to get the crop in before the rains come can mean the loss of a whole field . . . a loss which cuts deeply into profits when winter feed has to be bought to replace the rain-ruined hay.

Trouble with his machinery at harvesting time can mean serious loss to the farmer. That's why New Holland believes in good quality control measures . . . to catch and correct right at the factory anything which might cause trouble in the field. That's how controlled quality in the farm machinery plant helps save many a crop.

NEW HOLLAND
FIRST IN GRASSLAND FARMING
Farm Engineered Machinery
A Subsidiary of The Sperry Corporation

NEW HOLLAND MACHINE COMPANY, NEW HOLLAND PENNA. • SUBSIDIARY OF THE SPERRY CORPORATION

MINNEAPOLIS KANSAS CITY DES MOINES BRANTFORD, ONT.

Index to Quality Control Advertisers

MAY, 1952

Aluminum Company of America 52
American Bosch Corporation 148
American Steel & Wire Division, United States Steel Company 13
B. C. Ames Co. 69
Amplex Manufacturing Company, Subsidiary of Chrysler Corporation 14
Bausch & Lomb Optical Company 45
Bell Telephone Laboratories, Inc. 40
Bender Calculator Company 27
R. G. Bock Engineers 3
The Bossert Company 50
Bristol Laboratories Inc. 62
The Broderick Company 89
Brown & Sharpe Mfg. Co. 18
Bryant Chucking Grinder Company 11
Burgess Battery Company 115

J. I. Case Co. 129
Continental Motors Corporation 47
Cosa Corporation 28
Cummins Engine Company, Inc. 141

The Davison Chemical Corporation 136
Dearborn Motors Corporation 137
Deere & Company 15
The DeLaval Separator Company 131
Delco-Remy Division, GMC 134
The DoAll Company 51
Edward Don & Company 132
Allen B. Dumont Laboratories, Inc. 144
The Dumore Company 66

Eastman Kodak Company 5
Elliott Service Company 7
Engineers Specialties Division, The Universal Engraving & Colorplate Company, Inc. 4

Federal Products Corporation 150
Fuller Brush Company 8

General Electric Company 43
Graham-Mintel Instrument Company 9
Greenfield Tap & Die Corporation 67-68
Guide Lamp Division, GMC 120

Hamilton Beach Company, Division, Scovill Manufacturing Co. 114
Hunter Spring Company 17

Inland Automatic, Inc. 10
International Business Machines Corporation 6
International Harvester Company 147
Richard D. Irwin, Inc. 101

Johns-Manville Corporation 146
Johnson Gage Company 22
Jones & Lamson Machine Company 149
Kelsey-Hayes Wheel Company 143
King-Seeley Corporation 128

The Lamson & Sessions Co. 124
Lukens Steel Company 16

The Glenn L. Martin Company 127
McWane Cast Iron Pipe Company 109
Micrometrical Manufacturing Company 65
Minneapolis-Moline 123
Motorola, Inc. 122

New Departure Division, GMC 12
New Holland Machine Company 113
Norton Company 71

The Ohio Rubber Co. 125
Oldsmobile Division, GMC 145
The Oliver Corporation 119
Owens-Illinois Glass Company 139

Perfect Circle Corporation 121

Republic Steel Corporation 117
Rockbestos Products Corporation 34

Schenley Distillers, Inc. 130
The Sheffield Corporation 2
SKF Industries, Inc. 111
A. O. Smith Corporation 126
Solar Aircraft Company 142
Standard Gage Company 39
Sylvania Electric Products, Inc. 140

Taft-Peirce Manufacturing Company 21
Talon, Inc. 108
Tennessee Eastman Company 138
Thompson Products, Inc. 61
The Timken-Detroit Axle Company 133

United Air Lines 70
U. S. Department of Agriculture—Graduate School 103

Warner Gear Division, Borg-Warner Corporation 118
Western Electric Company 60
John Wiley & Sons, Inc. 105
Willys-Overland Motors 135

HAMILTON BEACH

Precision Quality Food Mixers

HAMILTON BEACH COMPANY

DIVISION

SCOVILL MANUFACTURING CO.

RACINE, WISCONSIN

FILM REVIEW

McGraw-Hill Text Films; 2nd Management Series — No. 5 Quality Control; 16 mm.; 10 minutes. Available from

McGraw-Hill Book Company
Text Film Department
330 West 42nd Street
New York 18, New York

Reviewed by John A. Henry, Professor of Mechanical Engineering, University of Illinois.

How superficial can a film on a technical subject become? This is a great deal like asking the question "How far is up", but an answer may be approximated by reviewing this film. It is intended as an auxiliary to a textbook in the management field, and suffers from an effort to pack too much in too little space. It may be useful for the college student who cannot read or the instructor who cannot speak.

Six minutes are devoted to mention of five general topics:

1. Production elements (man, machine, material)
2. Functional aspect of quality
3. Economic aspect of quality
4. Design tolerances
5. Inspection (line vs. crib and sampling vs. 100%)

Two minutes are devoted to statistical quality control, including variations in samples and a mention of sampling tables.

The closing two minutes inform the viewer that gages and measuring devices are nice to have around.

No basic principles are mentioned except variation in fraction defective, and none are explained. It is hard to conceive of an audience so naive that it could profit by such a film. Any one of the dozen or so ideas mentioned could be handled fairly well in the full ten minutes.

This reviewer has been earnestly seeking a real teaching aid—a sequence that would help explain one or more of the really tough ideas to put across, such as the relationship between averages and individual readings, or the basic sampling curves (OC, AOQ, ASN). The best general film is the one sponsored by an industrial firm and personally presented by a prominent member of the Society. A good film explaining principles should have a wide appeal for a variety of training programs, from the in-plant course through the college-level.

QUALITY CONTROL at
BURGESS
Is Your Assurance of Uniform Dry Battery Operation!

A Quality Dry Battery For Every Purpose

Yes—quality of product has been the guiding factor for more than forty years in the manufacture of Burgess Batteries. Burgess engineers first began the use of quality control methods 15 years ago to assure the user uniform high quality batteries. Today, quality control at Burgess is employed from incoming raw materials to the final test of assembled batteries. That's why two out of three electronic engineers today specify BURGESS; that's why BURGESS Batteries have been first choice of scientists and explorers.

Burgess has devoted more than 30 years to the production of batteries for special and industrial applications. Hundreds of types are available to industry through local Burgess distributors. Write to Burgess Battery Company for a catalog of descriptive information to assist you in ordering Burgess Batteries locally.

Enter *Your* Requirements With Us!

If you are designing a new battery-operated product and need a special battery, Burgess engineers will assist you in providing the correct battery. Handy check-sheet enables you to describe your exact requirements. Write for one today.

BURGESS BATTERY COMPANY
Freeport, Illinois

AMERICAN SOCIETY NEWS

EXECUTIVE COMMITTEE MEETS

The Executive Committee met in Cleveland on February 9 and 10, 1952. An important part of the time of this meeting was devoted to a careful discussion and study of the first report of the Section Representation Committee. This committee has been working diligently for several months to formulate a plan to modernize our Constitution. The rapid growth of the Society has caused it to outgrow its administrative set-up, and future inevitable further expansion imposes the necessity to revamp many of the features under which we have been operating with increasing difficulty. A comprehensive plan has been drawn up and this was approved by the Executive Committee and sent to the Board of Directors for their endorsement. If the Board approves the plan, it will be presented to the membership for a vote of "intent to comply," so that the mechanical details, which will require a full year to complete, may be initiated.

The Secretary reported that our membership as of February 6, 1952 was 5,290, and the Treasurer's report indicated a satisfactory financial situation. At the end of the second quarter of the fiscal year, 46.7% of the budget had been expended.

The Executive Secretary reported that by the close of the current fiscal year all miscellaneous phases of the Society's operations, except those exclusively associated with our publications and the Treasurer's office, will be consolidated in the New York office of the Society. We now own and operate our own mailing service, addressograph equipment, etc., which, in addition to reducing costs, will result in greatly improved service on all related subjects.

ST. LOUIS SECTION CONTRIBUTIONS

The Executive Committee of the St. Louis Section has forwarded to the President two checks for $25.00 each, specifying contributions to both the Shewhart Medal and Brumbaugh Award funds. This further generosity will help to implement the hopes of the original Brumbaugh Award Committee that the fund could some day be built up to the point where the annual award could be increased to $100.00 from its presently established $50.00. It is with great pleasure that recognition can be taken of the sincere interest our members have in the manner in which we honor our outstanding members. The Society is most grateful to the St. Louis Section for these contributions.

COMMITTEE MEETINGS AT CONVENTION

Due to the extended program features of the Convention, it has been necessary to fit in a schedule of Committee meetings during the Convention. This schedule, as of the time of going to press, appears under the "Events of Interest" section of the Convention Program elsewhere in this issue. However, committee members are urged to check the daily events boards in the hotels Syracuse and Onondaga, as well as at the Auditorium, for necessary last minute changes.

EDITORIAL BOARD

Under the five-year rotation plan adopted by and for the Editorial Board effective July 1, 1950, three new members will join this Board for a five-year term beginning July 1, 1952. The new Board members are:

Paul C. Clifford
Montclair State Teachers College
Leonard A. Seder
Gillette Safety Razor Company
W. J. Youden
National Bureau of Standards

Members retiring from the Editorial Board as of June 30, 1952 are:

Martin A. Brumbaugh
Bristol Laboratories
Frederick Mosteller
Harvard University
A. E. R. Westman
Ontario Research Foundation

The Society is deeply grateful to the retiring members for their guidance and loyal service to our journal, and welcomes with sincere pleasure the new members who will share responsibility for the further strengthening of Society publication policies.

BRUMBAUGH AWARD FUND

The Sixth Midwest Conference Planning Committee, recognizing the merit of this award and desiring to assist in insuring its continuance, has made a $100.00 contribution to the sustaining fund. The Society expresses its sincere appreciation and thanks for this generous act.

AUTOMOTIVE TECHNICAL COMMITTEE

Mr. S. C. Starnaman, Oldsmobile Division of G.M.C., Vice Chairman of the Automotive Technical Committee since its organization, has asked to be relieved from his assignment. We understand that Sid is going into business for himself as an automobile dealer, and we wish him the very best of success.

Mr. Nelson G. Meagley, Chairman of the Committee, is pleased to announce the appointment of Mr. A. C. Norris, Director of Quality Control, Hudson Motor Car Company, as Vice Chairman of his committee. We wish to welcome Mr. Norris into this important phase of Society activity.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls
FOUNDED IN 1945
References and Literature on Request
Senior Partner: W. E. JONES, *Fellow, ASQC*
699 Rose Ave., DES PLAINES, ILL. *Vanderbilt* 4-6533

Consulting Services in Quality Control
RALPH E. WAREHAM
Fellow, ASQC
122 Orchard Ridge, Chappaqua, New York
Telephone Chappaqua 1-0715

POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control, Room 5036, 70 East 45th Street, New York 17, N.Y.

QUALITY CONTROL ENGINEER. Age 37. Six years Quality Control experience in the electrical, mechanical, and chemical industries. Engineering and statistical degrees. Nationally known; many speeches and publications. Qualified for manager of Inspection and Quality Control or as engineer in large inspection, test, or research organization. Salary range: $10,000. Please reply to 8C1 at above address.

YOU STILL CAN HAVE

STAINLESS STEEL QUALITY

WITH *Enduro* TYPE 430

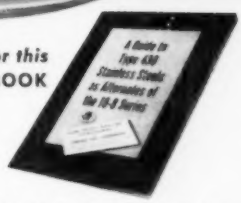
● In many cases, there is no reason today why current restrictions on nickel should deprive products of stainless steel quality. Many items formerly made from 18-8 types still can enjoy the advantages that only stainless steel can afford . . . by converting to Republic ENDURO Type 430.

Republic ENDURO Type 430 is not a new stainless steel. It has been in successful continuous service for 28 years in a wide variety of applications. Its corrosion-resistance is exceptionally good. It affords high yield strength. Its resistance to scaling and oxidation at elevated temperatures is high. It can be fabricated by all modern methods.

Many manufacturers already have converted to Type 430 or one of its modifications. Others are making plans to do so. Why don't *you* talk to a Republic Stainless Steel Metallurgist —and learn just how Type 430 can help you maintain stainless steel quality in your product? Contact your nearest Republic District Sales Office or write us.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.

Send for this NEW BOOK



You'll find it filled with facts to help you consider conversion to Type 430—*fast*. Write to: Republic Steel Corporation, 3132 E. 45th Street, Cleveland 27, Ohio.

Republic
REPUBLIC STEEL
ENDURO STAINLESS STEEL

Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Tubing, Lockers, Shelving, and Fabricated Steel Building Products

IT'S NO TRICK—

(if you know How!)

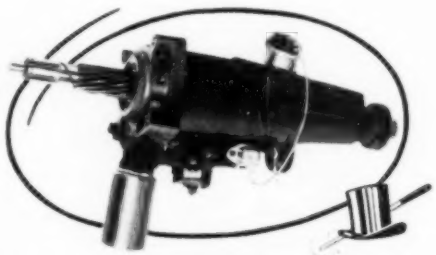
● It's no trick to mass produce a superior product if you know how — and the "know how" at Warner Gear Division relies implicitly upon statistical quality control.

Long a major supplier of original equipment to the automotive industry, Warner Gear Division has *always* maintained rigid control standards in every operation, adopting newer and better methods and devices as they have been introduced and proved.

Such complicated assemblies as the Overdrive and the Automatic Torque Converter transmission require many exacting inspections — absolute tolerance limits and a running record of the accuracy maintained.

Automotive manufacturers, the world over, know that a product or part, designed, engineered and built by Warner Gear will stand the test of usage and time — and the public, too, has developed a preference for Warner Gear products as evidenced by the constantly growing demand for Overdrives.

More than four and a half million Overdrives have been sold to date — every single one of them reflecting the individual care exercised in Warner Gear production.

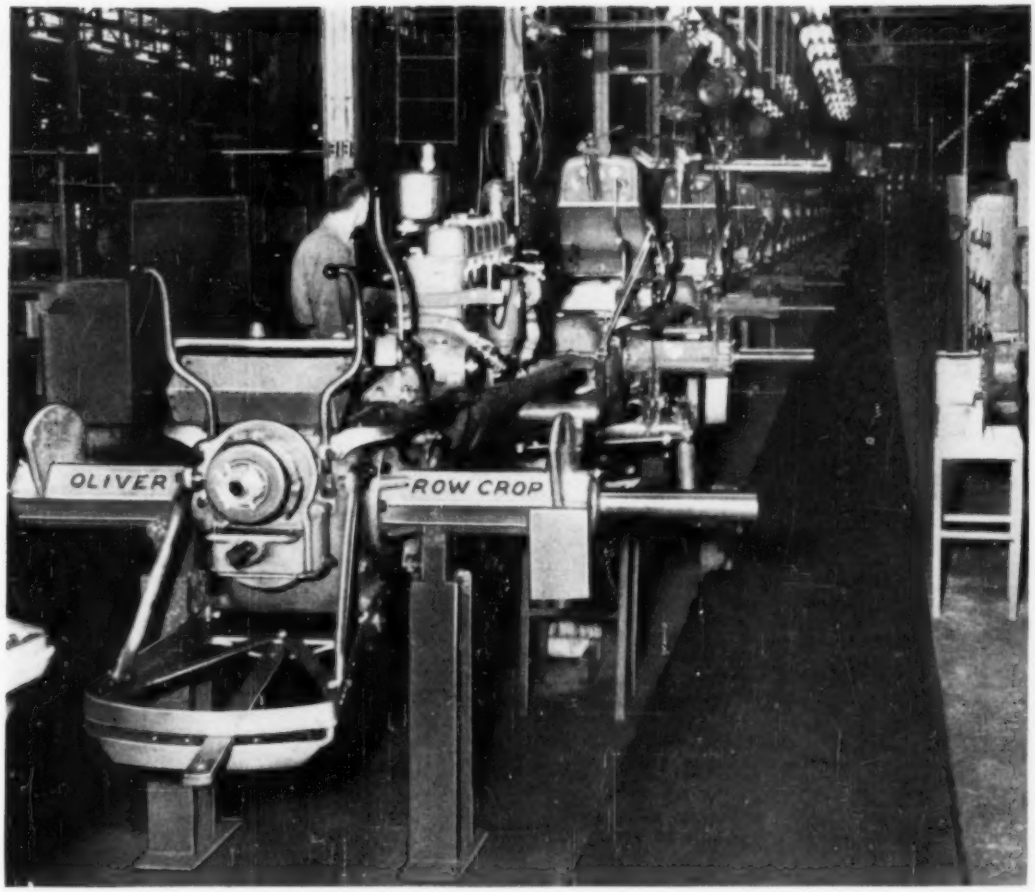


OVER 4½ MILLION OVERDRIVES HAVE BEEN SOLD!

ENGINEERING B-W PRODUCTION

Warner Gear *Division*

BORG-WARNER CORPORATION • MUNCIE, INDIANA, U.S.A.



We Keep Them in Line...

All along the line at Oliver there is an unrelenting adherence to rigid specifications.

For quality is a basic Oliver principle that's inherent in design, materials and workmanship. Thus, quality *control* is a fundamental standard in Oliver's everyday operations, in every phase of manufacture and assembly.

A combination of up-to-date production equipment, *modern methods of testing* and a staff of capable craftsmen enables Oliver to offer agriculture and industry the finest equipment money can buy. The OLIVER Corporation, 400 West Madison Street, Chicago 6, Ill.

THE OLIVER CORPORATION

OLIVER

"FINEST IN FARM AND INDUSTRIAL MACHINERY"

GUIDE

lives up to its name...

For more than a generation, Guide has lived up to its name by building lamps that truly *light the* way for vehicle owners . . . that *lead the* way in quality and performance.

* * *

Guide is the world's largest manufacturer of automotive and tractor lighting equipment. Each night Guide lamps give freedom of movement to millions of passenger cars, trucks, buses and tractors.

* * *

Guide, of course, maintains its leadership through the exercise of constant quality control. Every step in the manufacture of Guide lamps is closely supervised, and the finished product must meet exacting standards in both appearance and operation.

* * *

Guide Lamp has lived up to its name by building products that are superior in capacity, rugged in construction, dependable in service. Guide has lived up to its name by keeping quality first.

SEALED BEAM UNITS

HEADLAMPS

TAIL LAMPS

PARKING LAMPS

TURN SIGNALS

SPOT LAMPS

FOG LAMPS

GLARE-PROOF MIRRORS

GUIDE LAMP

DIVISION OF GENERAL MOTORS

ANDERSON, INDIANA

On every tap (pour of molten metal), iron technicians at Perfect Circle foundries run and record tests to determine temperature, hardness, and iron fracture. 70 to 80 complete checks are made during each eight hour shift to assure uniform, high quality castings. Here the technician is running the pyrometer test for temperature tabulation.

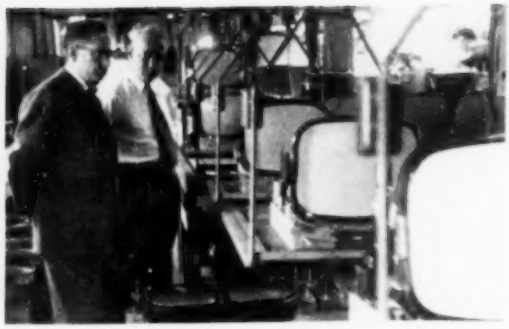
Constant improvement

Statistical Quality Control has been effective at Perfect Circle in improving P.C. products, increasing production, and reducing unit cost. It is because of this proven service that Perfect Circle's objective is to have all phases of production benefit from proper application of statistical control techniques. Perfect Circle Corporation, Hagerstown, Indiana.

Perfect Circle PISTON RINGS

The Standard of Comparison

Merciless Vibration Test



Severe "Hot Line" Power Test

a "SHIMMY" and a "SHOCK" for finest TV!

DOUBLE-CHECKING SIDESTEPS TROUBLE – Every step of production is in the hands of highly skilled, qualified technicians, yet their human fallibility is policed by critical inspectors who check all previous operations in chassis assembly as it proceeds through production.

A television set must be prepared to do *more* than produce a picture. Before it steps into a packing carton for its journey from factory to living room, it must be pre-conditioned to meet the possible hazards of its life-span. This extensive check-test program is an integral part of the *good engineering* that produces Motorola TV. One of the most important of these tests is the mechanical "shake table" whose high speed "shimmy" reveals any loose parts, unstable wiring or connections, at the same time ridding the chassis of extraneous particles of solder, etc. Equally important is the high voltage "shock" surge test to which the completed chassis and mounted picture tube are submitted, a sure-fire method to show up faulty wiring or short-life parts.

SAFE "HIGH-WAY" TRAFFIC – Husky overhead "claw" conveyors move completed TV sets, packed in safety-tested cartons, speedily and smoothly from packing department to shipping room, where the "last lap" of delivery begins.

THE PICTURE TELLS THE STORY – No eye is more critical than the trained engineers' who give Motorola TV its final inspection, and 100% perfection in picture quality, sound and operation is the requirement for their stamp of approval. Finest possible performance, produced to precision standards of quality – above and beyond mere picture perfection – is the qualification for a final "O. K."

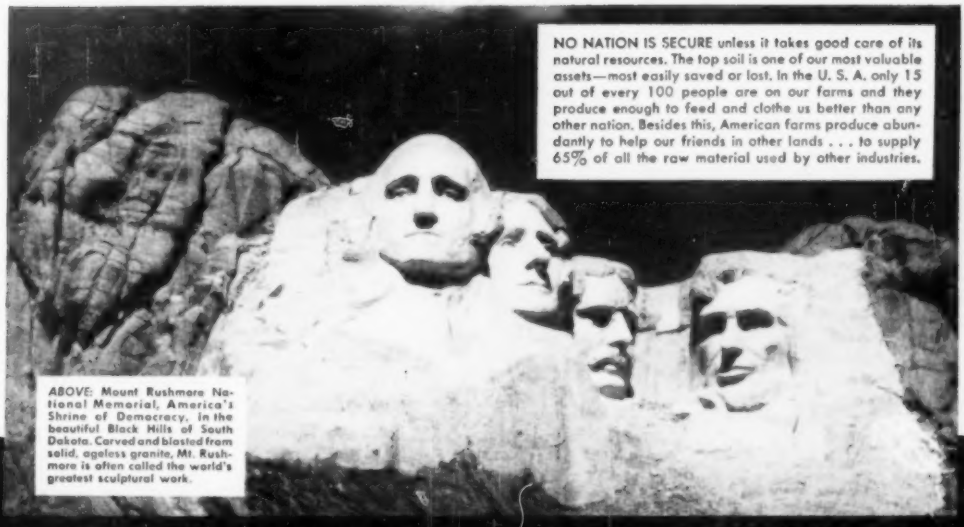
24 Years of Leadership
in good engineering

RESEARCH ENGINEERING DIVISION

Motorola Inc.

4545 AUGUSTA BLVD., CHICAGO 51, ILL.

These four Farmer-Statesmen found the "Roots of Freedom" in the soil!



NO NATION IS SECURE unless it takes good care of its natural resources. The top soil is one of our most valuable assets—most easily saved or lost. In the U. S. A. only 15 out of every 100 people are on our farms and they produce enough to feed and clothe us better than any other nation. Besides this, American farms produce abundantly to help our friends in other lands . . . to supply 65% of all the raw material used by other industries.

ABOVE: Mount Rushmore National Memorial, America's Shrine of Democracy, in the beautiful Black Hills of South Dakota. Carved and blasted from solid, ageless granite, Mt. Rushmore is often called the world's greatest sculptural work.

"I know of no pursuit in which more real and important service can be rendered to any country than by improving its agriculture . . ."

—GEORGE WASHINGTON

"The Farmer: The Cornerstone of Civilization."

—THEODORE ROOSEVELT

"Let the farmer forevermore be honored in his calling—for they who labor in the earth are the chosen people of God."

—THOMAS JEFFERSON—

". . . no other human occupation opens so wide a field for the profitable and agreeable combination of labor with cultivated thought, as agriculture."

—ABRAHAM LINCOLN

You can help preserve that freedom through sound soil conservation

Your freedom . . . America's freedom . . . is rooted in the topsoil!

Washington knew this when he spoke out for soil conservation. Jefferson, Roosevelt and Lincoln knew it when they spoke for agriculture. Because they were farmers themselves, all four knew that hunger and poverty breed war and strife . . . that food and the products of the farm are powerful weapons for peace and freedom. They knew, too, that America's agriculture and the enterprising American farmer were, and are, keys to American greatness . . . that the industry of the soil was, after all, the basic industry of any nation.

Today, those things . . . the peace and freedom that hinge on farm production . . . are in the hands of you, the American farmer. *That* is why *soil conservation* is important both to you and to America.

Year after year more of America's future washes away—needlessly. Is anything being done about it? Yes, thousands of modern farmers like yourself are seeing the need for sound conservation practices and *are* attacking the problem. Typical are the farmers who have organized and manage 2500 non-political Soil Conservation Districts. Sure, it has cost them some money as an original investment. But ask a soil conservation man and he'll tell you that his land pays him many times over what he puts into it. Increased production pays back the principal plus increased yields. Then too, the generations of the future who will continue to live by the land, will benefit as even you do.

If you are interested in the program of Soil Conservation Districts, see your MM dealer today or write to the United States Department of Agriculture, Washington, D. C. Ask for complete information on establishing a soil conservation district in your neighborhood. You too, will find that the "Roots of Freedom" are in the topsoil . . . and they will be stronger because of you.

HELPFUL FACTS ABOUT SOIL CONSERVATION DISTRICTS

- Soil Conservation Districts are made possible by your own state laws.
- Operate independently of any federal law or regulation.
- Do not handle any such federal programs as marketing agreements, market quotas, acreage allotment or crop insurance.
- Get the conservation job done by local people through local effort in the American way.
- There is no charge for the technical and other district help that is available to apply a conservation plan to your farm.

MM

MINNEAPOLIS-MOLINE

MINNEAPOLIS 1, MINNESOTA

MANUFACTURERS OF THE COMPLETE LINE OF MODERN VISIONLINED TRACTORS, FARM MACHINERY AND POWER UNITS FOR AGRICULTURE

LAMSON & SESSIONS

Statistical Quality Controlled FASTENERS

Lamson & Sessions

The LAMSON & SESSIONS *Co.*
1971 West 85th St. • Cleveland 2, Ohio
Plants at Cleveland and Kent, Ohio • Birmingham • Chicago

THE HOME OF QUALITY CONTROLLED FASTENERS

at the Ohio Rubber Company

A Progress Report

OBJECTIVES

Statistical Quality Control has proved to be an effective management tool for the Ohio Rubber Company. Our prime objective is to apply it wherever its use will result in practical advantages to our customers or ourselves.

ORGANIZATION

The S. Q. C. Department of The Ohio Rubber Company is a distinct, but integral unit of our organization. It functions in close coordination with our Inspection Department and with Management, Sales Engineering, and Supervisory Personnel.

Our S. Q. C. Department is staffed by an experienced Quality Control Engineer and several trained analysts. The department reports to the Chief Inspector. Inspection work is performed by Inspection Department personnel, using methods established by the S. Q. C. Department.

INCOMING MATERIAL CONTROL

Systematic engineered sampling and detailed inspection procedures on a wide variety of metal stampings, forgings, machined parts, and non-metallic parts used in rubber-to-metal technical products have reduced defectives in processing and raised quality of finished products.

PROCESS CONTROL

Effective use of Fraction Defective charts has produced higher quality and significant savings in such operations as multi-cavity molding, punching and trimming of various products including automobile floor mats. Additional applications include packaging and internal materials handling.

SPECIAL PROJECTS

Important problems are solved by applications of S. Q. C. methods in such special projects as tolerance build-up, quicker detection and correction of errors in weight scale counters, process capability studies and many others.

FUTURE PLANS

With many successful applications of S. Q. C. already made, our confidence in the benefits of such a program has led to complete management support of future applications in Outgoing Material Auditing, Quality Certification, and other phases of our operations.

HERMON F. SAFFORD
President
THE OHIO RUBBER CO.
Willoughby, Ohio

We've met before!

IF YOU DRIVE A CAR, chances are it has an A.O. Smith frame. We've made millions of welded frames for almost all makes of cars since before the days of the Model "T."

Gasoline consumed by your automobile, in all probability came from refineries where A.O. Smith welded vessels, towers and tanks distill, refine and collect the many products of oil.

THOUSANDS OF MILES of A.O. Smith welded line pipe carry these petroleum products to market. Thousands more miles of A.O. Smith pipe in diameters to 30 inches connect gas wells to distributing systems that supply your home with gas for cooking, heating and water heating.

SLAKE YOUR THIRST with beer? No doubt it was aged and stored at the brewery in A.O. Smith welded, glass-lined tanks.

EVEN YOUR MILK this morning and your dinner roast or steak may have come from cattle fed on silage stored in an A.O. Smith glass-surfaced steel Harvestore.

WHEREVER YOU TURN, you encounter products welded by A.O. Smith welding machines and welding electrodes . . .

INCLUDING FAMOUS *Permaglas* longer-lasting, can't-rust, automatic water heaters with glass-fused-to-steel tanks.

Everywhere we serve one another . . . you, by demanding better products and services for your needs . . . we, by continuing the development of new and better ways to design and fabricate the products required.

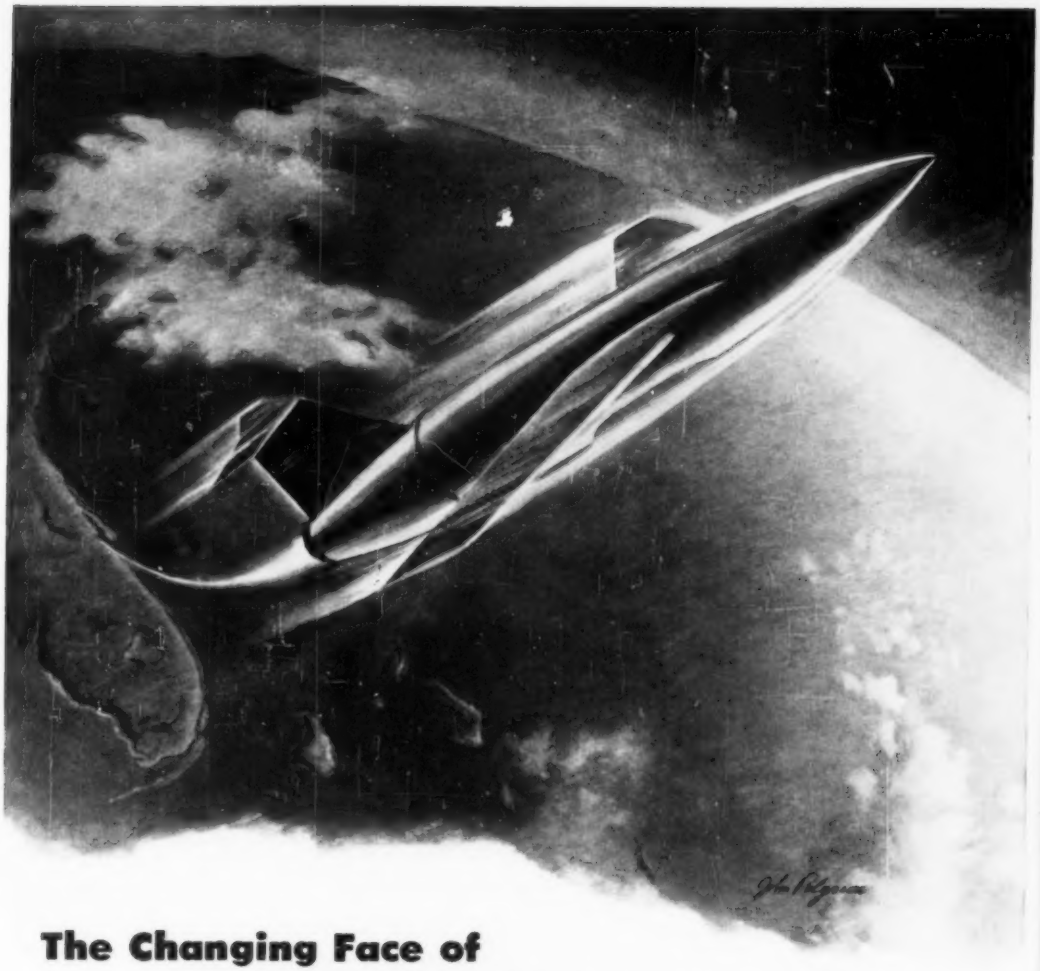
Research & Engineering Building

78th ANNIVERSARY

A.O. Smith

CORPORATION

Factories at Milwaukee • Kankakee, Ill.
Houston • Los Angeles • Toledo • Succasunna, N.J.
Tipp City, O. • Elkhorn, Wis.



The Changing Face of America's Air Power

is mirrored in a pilotless bomber roaring skyward at the Air Force Missile Test Center . . . in a Navy high-altitude research rocket soaring into the outermost frontiers of the earth's atmosphere . . . in an Air Force night intruder jet bomber racing to attack targets veiled by darkness . . . in a Navy anti-submarine seaplane probing electronically for undersea raiders . . . in a modern airliner speeding passengers and vital cargo on essential missions.

We take pride in the fact that Martin developments and Martin men and women are part of the technical team of men and machines that is America's best guarantee of continued U. S. air supremacy.

THE GLENN L. MARTIN COMPANY, Baltimore 3, Md.

Martin

AIRCRAFT

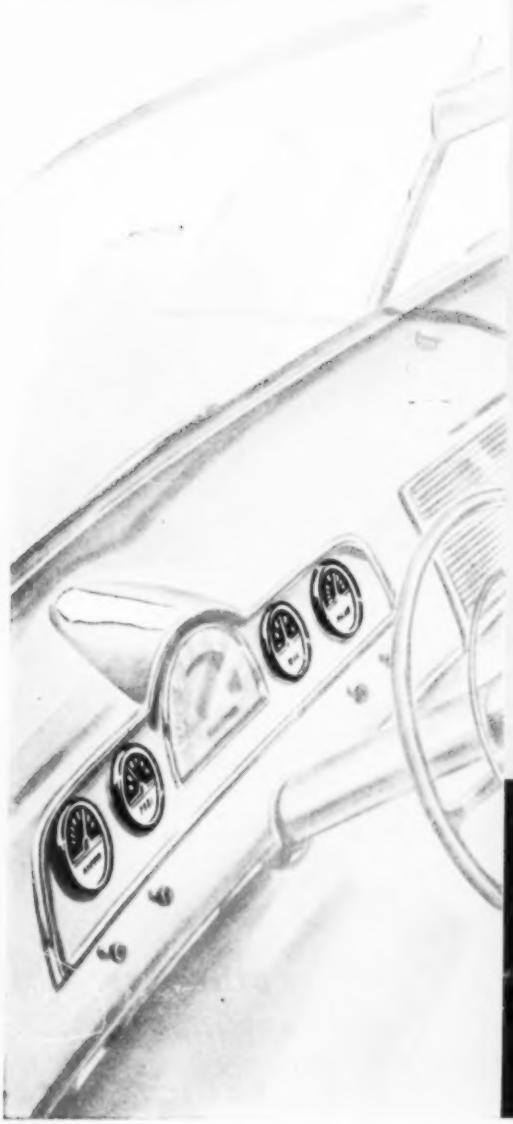
Builders of Dependable Aircraft Since 1909

Developers and Manufacturers of: Navy P5M-1 Marlin seaplanes • Air Force B-57A Canberra night intruder bombers • Air Force B-61 Matador pilotless bombers • Navy P4M-1 Mercator patrol planes • Navy KDM-1 Plover target drones • Navy Viking high-altitude research rockets • Air Force XB-51 developmental tactical bomber • Martin airliners • Guided missiles • Electronic fire control & radar systems • **Leaders in** Building Air Power to Guard the Peace, Air Transport to Serve It.

Illustration is artist's conception of Air Force B-61 Matador pilotless bomber.

KS DASHBOARD INSTRUMENTS

Manufactured Under Rigid Quality Control



Oil Pressure Telegage

Water Temperature Telegage

Fuel Level Telegage

Ammeter

Scientific Quality Control governs all manufacturing and assembly operations involved in the production of K S dashboard instruments and instrument clusters for passenger cars and trucks.

As a result these instruments are dimensionally accurate, easy to install; they function uniformly and assure the ultimate user years of uninterrupted service.

King-Seeley engineers are always at your service.

KING-SEELEY CORPORATION

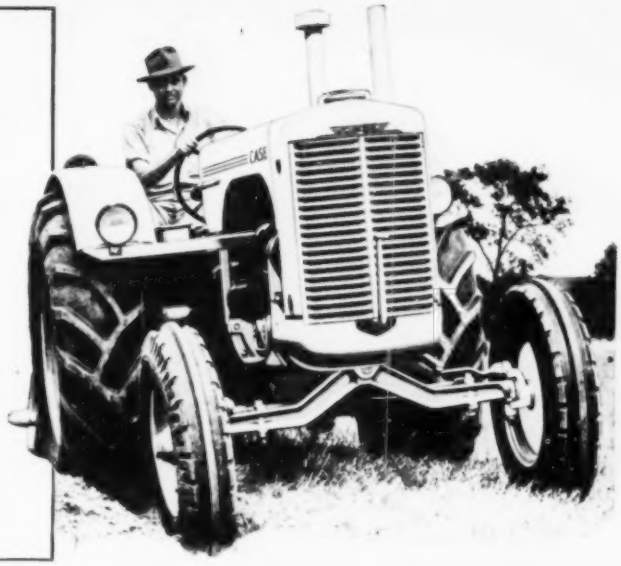
ANN ARBOR, MICHIGAN

PLANTS IN

ANN ARBOR SCIO

YPSILANTI

THREE THINGS Make a Product Great



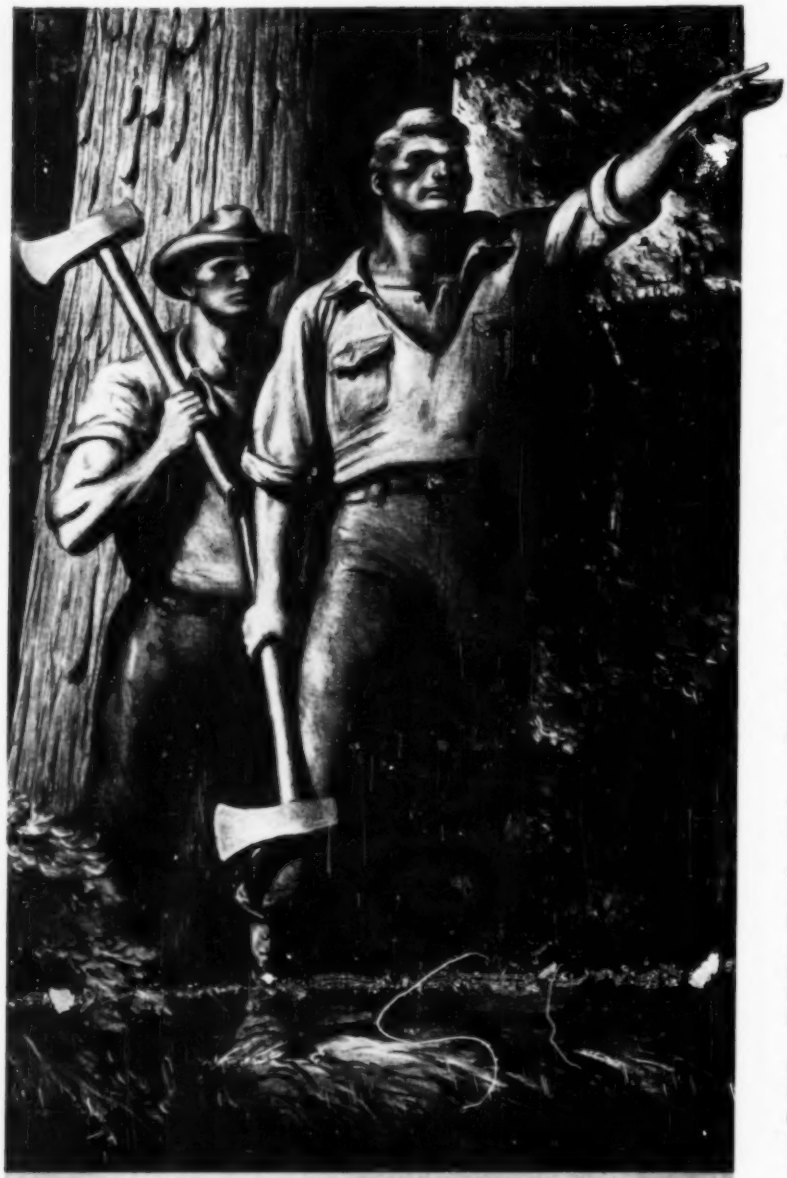
Three things make an industrial product great. There is the creative thinking that goes into its inception and design. There is the skill in the hands of the men and women who build it and send it on its way. And there is the excellence of the steels, the rubber, the wood and the fabrics that are shaped into the form and function of that product. All are bound inseparably by the time-tested integrity of the manufacturer.

Excellence of materials! Therein is embraced much of science and all of an art—quality control. It is the rigid adherence to exact specifications in raw materials, and the constant testing of random samples as they converge at the assembly line, that have won for Case farm and industrial tractors and Case farm machines their proved endurance, their world-wide esteem for more than a century.

Long a leader in the big-power class, the Case Model "LA" tractor owes its leadership to this three-fold industrial idealism. Its famous forebear, the doughty Model "L," led the field for many years. Even today there are Case "L" tractors in hard daily use after more than 20 years—and still going strong. This remarkable longevity and customer satisfaction bear testimony to the Case practice of quality control. J. I. Case Co., Racine, Wis.

America's favorite combine, the 6-foot Case Model "A," is another example of correct design given endurance by quality control. The continuing good work and long life for which the "A" combine is famed are results of the Three Things—creative thinking, honest workmanship, and quality control.

CASE



Barrel Hunt in the Ozarks

Out of all the different trees in the world, only one kind makes the best barrels for aging whiskey. It is the white oak that grows high on the wind-swept Ozark Mountains.

Fortunately, this oak is abundant. And with reforestation, we need fear no shortage in the years to come.

When the giant oaks mature and are felled, Schenley takes the heart wood for its craftsmen to work into sturdy whiskey barrels. This hard center wood has many superior qualities, chars perfectly for aging whiskey.

Many whiskey makers don't go to the trouble of making their own barrels. You may wonder why Schenley does. It's part of a complete network of quality controls which guard the goodness of Schenley whiskies from the time the grain is grown till the whiskey is in your glass.

This is Schenley's way of making certain that you get the utmost enjoyment in every drop of every drink. *Schenley Distillers, Inc., New York, N. Y.*

Nature's unhurried goodness

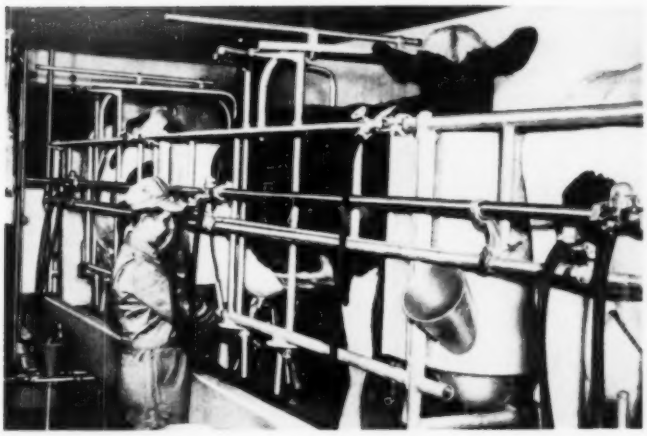
\+ S =

Schenley's unmatched skill

The best-tasting whiskies in ages

SCHENLEY

DE LAVAL PROVIDES "Two-Way" QUALITY CONTROL



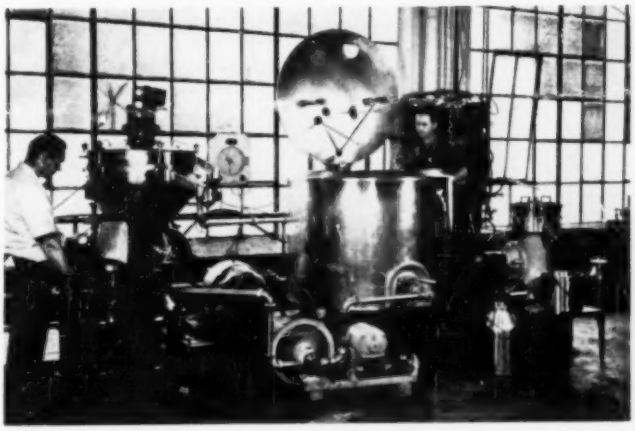
....To Agriculture

We furnish the milking equipment, cream separators, milk clarifiers and water heaters which make it possible for dairymen to produce the highest quality milk, cream, butter, cheese and other dairy products.

Here at De Laval we have been successfully meeting a "two-way" quality control challenge for **74** years. Our methods of quality control have resulted in the unvarying high precision and top performance for which our products are known. And these carefully safeguarded qualities of precision and performance have, in turn, provided our customers in both agriculture and industry with the essential quality control they require in their own production.

....To Industry

We supply the many types of industrial centrifugals which are essential equipment in almost every phase of American industry—metal working, marine, power, chemical, pharmaceutical and others.



THE DE LAVAL SEPARATOR COMPANY

POUGHKEEPSIE, N. Y.

EDWARD DON & COMPANY

Back of Each of 50,000 Items Sold by DON is an Institution of Service and a Guarantee of Satisfaction!

Everything You Need . . . When You Need It!

EQUIPMENT, FURNISHINGS & SUPPLIES

Whether it be a carton of toothpicks or a battery of kitchen ranges—a case of toilet tissue or a dish washer, no matter what you buy here, it is guaranteed! Back of our *written* guarantee on EVERY ITEM is the name and reputation of DON. And in addition to QUALITY, VALUE, CHOICE and positive SATISFACTION, you get the service you're entitled to! Each order is shipped quickly—*usually the very same day it is received!*

A few of the 50,000 items sold by DON and listed below may suggest something you need NOW!

Reminder CHECK LIST:

- Coffee Urns
- Springs and Mattresses
- Silverware
- Trays and Covers
- Towels (Paper-Cloth)
- Electric Vegetable Peelers
- Floor Matting
- Sinks (Stainless Steel—Galvanized)
- Double Boilers
- Chinaware
- Tables and Chairs
- Floor Maintenance Machines
- Ovens (Gas-Electric)
- Towel Dispensers
- Ash Trays and Stands
- Mixers (All Kinds)
- Polishes and Cleaners
- Bar Stools
- Menu Covers
- Pots and Pans
- Lamps
- Bed Linens
- Dish Washers
- French Fry Cutters
- Utility Carts
- Cutlery
- Deodorizers
- Guest Room Furniture
- Toasters
- Spreads and Blankets
- Water Pitchers
- Mops and Brushes
- Ice Chippers
- Plastic Tableware
- Roll and Food Warmers
- Water Coolers
- Bar Supplies
- Steam Tables
- Soaps and Detergents
- Table Linens and Napkins
- Can Openers
- Vacuum Cleaners
- Uniforms
- Hospital Supplies
- Butter Cutters
- Electric Clocks
- Ranges and Broilers
- Glassware
- Paper Cups and Straws
- Curtains
- Coffee Makers
- Sanitation Supplies
- Toilet Tissue
- Juicers
- Disinfectants and Germicides
- Sand Urns
- Garbage and Storage Cans
- Food Grinders and Slicers
- Soda Fountain Supplies
- Floor Coverings
- Novelties—Party Supplies

Views of the DON permanent Exhibition Hall. You're always welcome.

SELF MEMO
(Write down what else you need)

_____

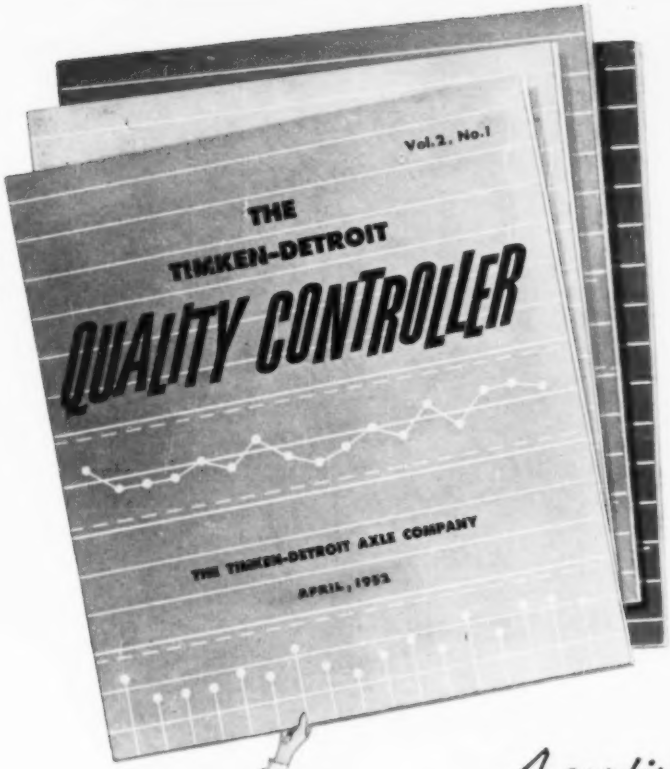
_____

_____

Talk it over with your DON salesman—write or telephone!

EDWARD DON & COMPANY

Dept. 80 • 2201 S. LaSalle • Chicago • Ph. CA 5-1800



A continuing program at

TIMKEN-DETROIT

At The Timken-Detroit Axle Company both management and employees are kept Quality-Control-conscious by this interesting and informative publication. Distributed regularly to all employees in their pay envelopes throughout Timken-Detroit's nine great plants, each pocket-size issue is devoted entirely to the subject of Industrial Quality Control—what it is, how and why it is used, and its importance to every man and woman in the Company. Here, indeed, is tangible evidence that The Timken-Detroit Axle Company is *promoting and practicing* Industrial Quality Control.

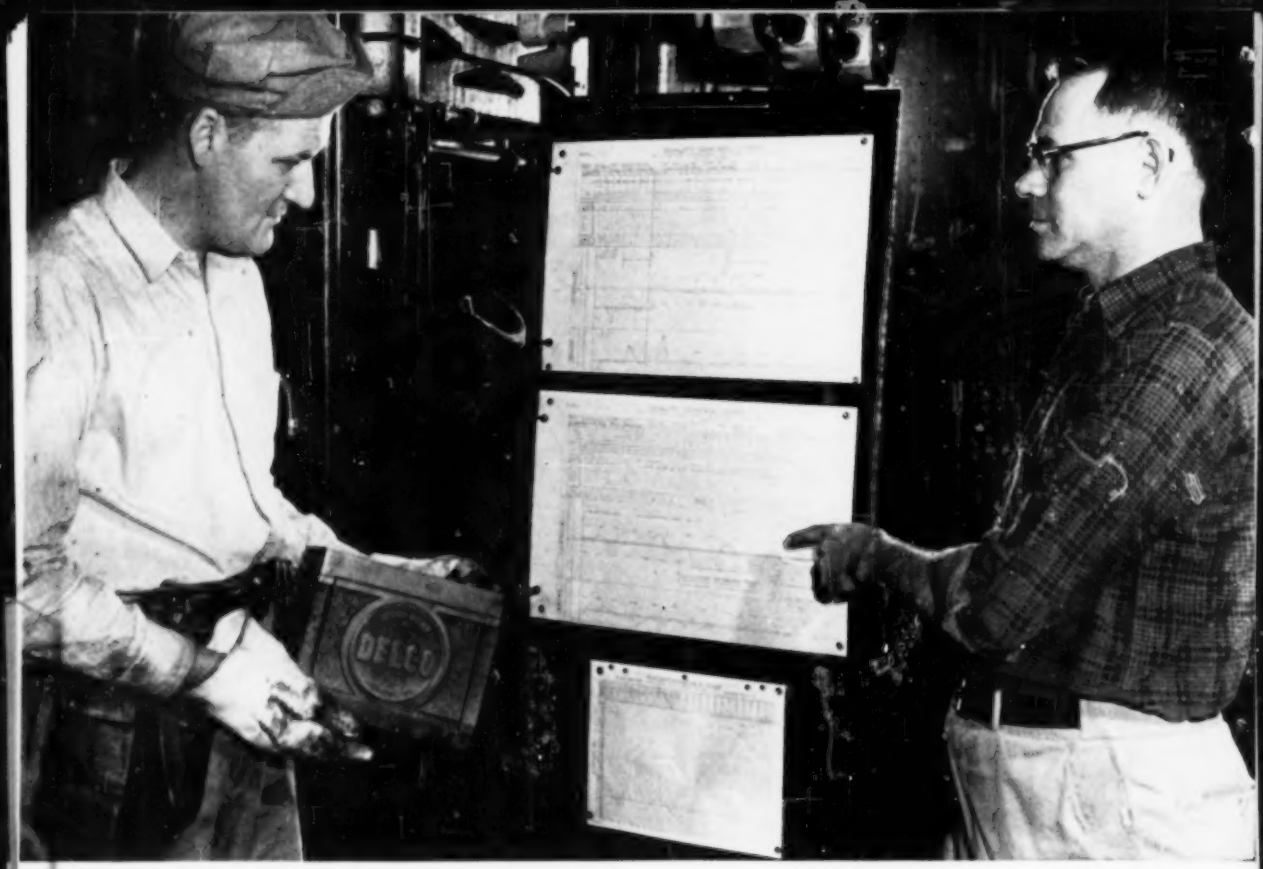
TIMKEN *Detroit* AXLES

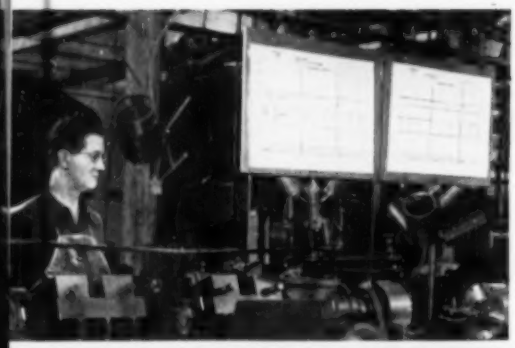
A PRODUCT OF THE TIMKEN-DETROIT AXLE COMPANY
DETROIT 32, MICHIGAN

The Accepted Standard

TRADE MARK REGISTERED

PLANTS AT: DETROIT AND JACKSON, MICH. • OSHKOSH, WIS. • UTICA, N. Y. • ASHTABULA, KENTON AND NEWARK, OHIO • NEW CASTLE, PA.





CHARTING A COURSE

to higher quality

The pictures on this page show dramatically how Delco-Remy charts a course to higher quality in the manufacture of automotive electrical equipment. All along the production line, Delco-Remy products are subjected to rigid inspections and tests. The many quality control charts reflect the high standards which have been a Delco-Remy tradition for more than 50 years.

DELCO-REMY

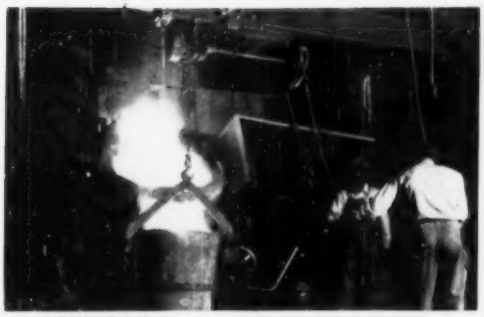
DIVISION • GENERAL MOTORS CORPORATION
ANDERSON, INDIANA

AUTOMOTIVE, TRACTOR AND MARINE ELECTRICAL EQUIPMENT

Through Integrated Production Operations

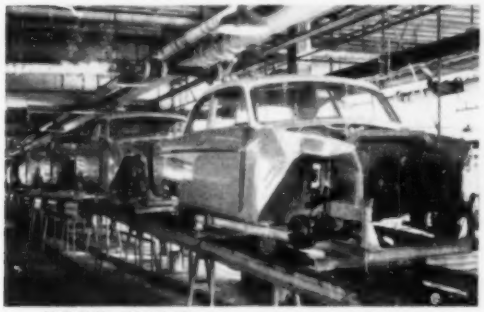
Willys-Overland Controls Quality

From Materials to Finished Products



FOUNDRY—All of the blocks used for Willys-Overland engines are cast in its foundry at Pontiac, Michigan.

FORGE—Willys-Overland produces forgings to the highest standards of quality control in its forge shop.



BODY PLANT—Statistical methods of physical inspection assure uniformly high quality of each unit.

ENGINE PLANT—Here is some of the precision equipment used in the Willys-Overland engine plant.

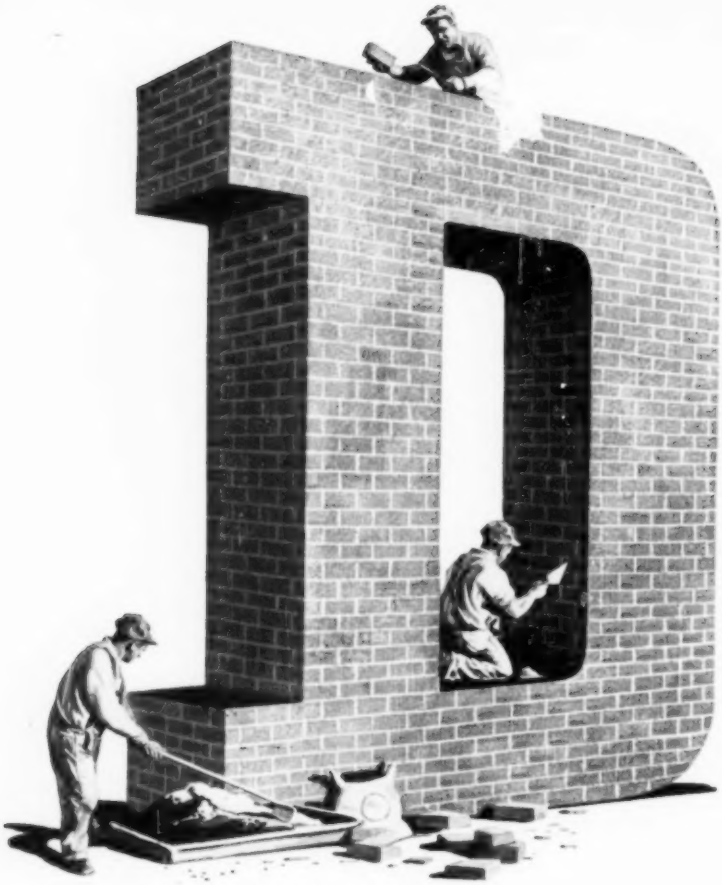
As a pioneer of statistical quality control, Willys-Overland uses advanced scientific methods recognized throughout industry. With its integrated production operations, such as those shown above, Willys-Overland carefully controls quality at every stage of manufacture, from materials to finished products.

As a leading manufacturer of military vehicles, Willys-Overland meets exacting standards required by the Government—standards which Willys-Overland also meets in its civilian production.

WILLYS-OVERLAND MOTORS

TOLEDO 1, OHIO

MAKERS OF AMERICA'S MOST USEFUL VEHICLES



Building for the Future . . .

The Chemical Processing Industries are expanding to meet the world demands for new and better products. The Davison Chemical Corporation, an important contributor to this expansion, is also building for the future. As our own business expands, we are able to broaden our service and to create new products for industry and agriculture. Davison facilities, products and technical experience are always available to help you build for the future.

Progress Through Chemistry

THE DAVISON CHEMICAL CORPORATION

Baltimore 3, Maryland

PRODUCERS OF: CATALYSTS, INORGANIC ACIDS, SUPERPHOSPHATES, PHOSPHATE ROCK, SILICA GELS AND SILICOFLUORIDES
SOLE PRODUCERS OF DAVCO GRANULATED FERTILIZERS

Ford Tractor parts get tough "Physicals" too!

At the left, a Ford Tractor crankshaft proves its internal integrity by means of the giant X-Ray Machine that "sees" through steel. At the right another Ford Tractor part establishes its dimensional accuracy, with the aid of a "comparator". This magnifies profiles of gear teeth, for example, by hundreds of times, so imperfections can be *detected and rejected!*

Ford employs the precision testing, gauging and analyzing inspection instruments and processes of the automotive industry, to mass-produce tractor parts, and tractors. Thus, Ford is able to mass-assemble tractors on assembly lines that closely match automotive production efficiency. That's why Ford Tractors can be priced so low. It's why Ford Tractor quality, from raw material to finished product, is so completely dependable. And the tough "physicals" given Ford Tractor parts assure the fit and fitness of repairs—in Topeka, Tampa or Tacoma!

Ford TRACTOR

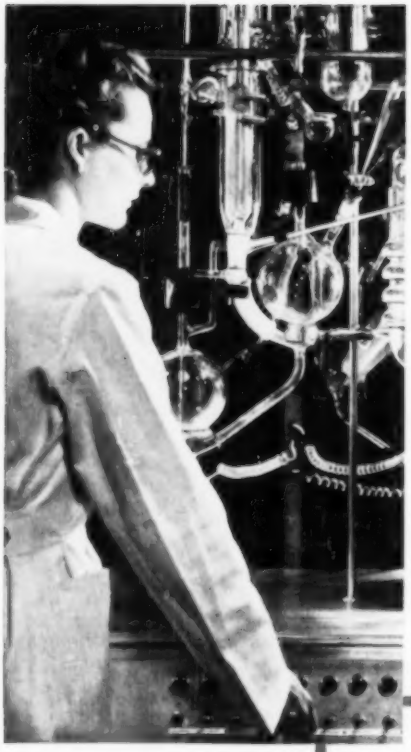
No wonder Ford Tractors are getting an ever increasing responsibility in helping grow the crops and building farm prosperity—to keep America well fed and strong!

DEARBORN MOTORS CORPORATION

BIRMINGHAM, MICHIGAN

National Marketing Organization for the Ford Tractor and Dearborn Farm Equipment

Ford Farming MEANS BETTER WORK ... MORE PRODUCTION



Quality control at Eastman starts in the laboratory. It follows through every phase of production. Whether you buy textile fibers, plastic compounds, or industrial chemicals, a uniform high quality is assured.

ESTRON ACETATE YARN AND STAPLE

TENITE PLASTICS

EASTMAN INDUSTRIAL CHEMICALS

Tennessee Eastman Company

DIVISION OF EASTMAN KODAK COMPANY

KINGSPORT, TENNESSEE

The Duraglas Center —
World's largest glass container
research laboratory

first in...
glass packaging experience

The Duraglas Center is a concentration of scientific forces seeking greater efficiency in the search for the best glass container, the best closure and the best carton; the most efficient means of using them; and the most effective support of a broad market development effort for our customers.

It is largely because of such efforts, combined with advanced manufacturing techniques guided by quality control, that Duraglas containers are now more durable than ever before . . . and shipping performance, once a matter of trial and error, has progressed to learning-by-engineering.

OWENS-ILLINOIS GLASS COMPANY

Manufacturers of Duraglas Quality Containers for Quality Products

Toledo 1, Ohio . . . Branches in Principal Cities

A page from the note-book of Sylvania Research

Sylvania Research Improves Semiconductor Performance

Development of improved processes for producing germanium crystals and improved methods of measuring their properties is a continuous program of the Sylvania Research Laboratories. The result is an ever increasing proficiency of semiconductor devices such as Sylvania germanium diodes and varistors.

The range of useful work performed by the many forms of Sylvania germanium crystals in communications and other electronic applications seems almost without limit. It fully justifies the large investment in research which Sylvania puts behind it. And it is another reason for Sylvania leadership in the world of electronics.

In the illustration, the fixture holds a sample of germanium to which electrical connections are made by means of tungsten wire whiskers. The pressure of contact is controlled by the knurled micrometer knob at the right. When the proper voltages are applied, a pattern is produced on the oscilloscope which permits the technician to measure electrical properties of the crystal and to study variations due to changes in methods of preparation.

SYLVANIA

Sylvania Electric Products Inc., 1740 Broadway, New York 19, N. Y.

TELEVISION PICTURE TUBES; ELECTRONIC TEST EQUIPMENT; ELECTRONIC DEVICES; RADIO TUBES; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

Cummins® Diesels
do so many jobs-so much better

Shovels, cranes, industrial locomotives

Drilling rigs, centrifugal pumps, generator sets

Buses and on-highway trucks

...because they're custom-built to fit the job

Earthmovers, logging yarders and loaders

Off-highway trucks, crawler tractors

Work boats, pleasure craft

Lightweight, high-speed Diesels (50-550 hp) for these and many other uses

---

...because they're

BUILT NOT ONCE BUT TWICE

Rugged, lightweight, high-speed Cummins Diesels are at work everywhere. Each engine is built *twice*. It's assembled, run-in tested, disassembled and inspected, then reassembled and tested again. This extra care in building, plus Cummins exclusive fuel system and an efficient and expanding service and parts organization, means minimum "down time", more power and profits for the user. See your Cummins dealer.

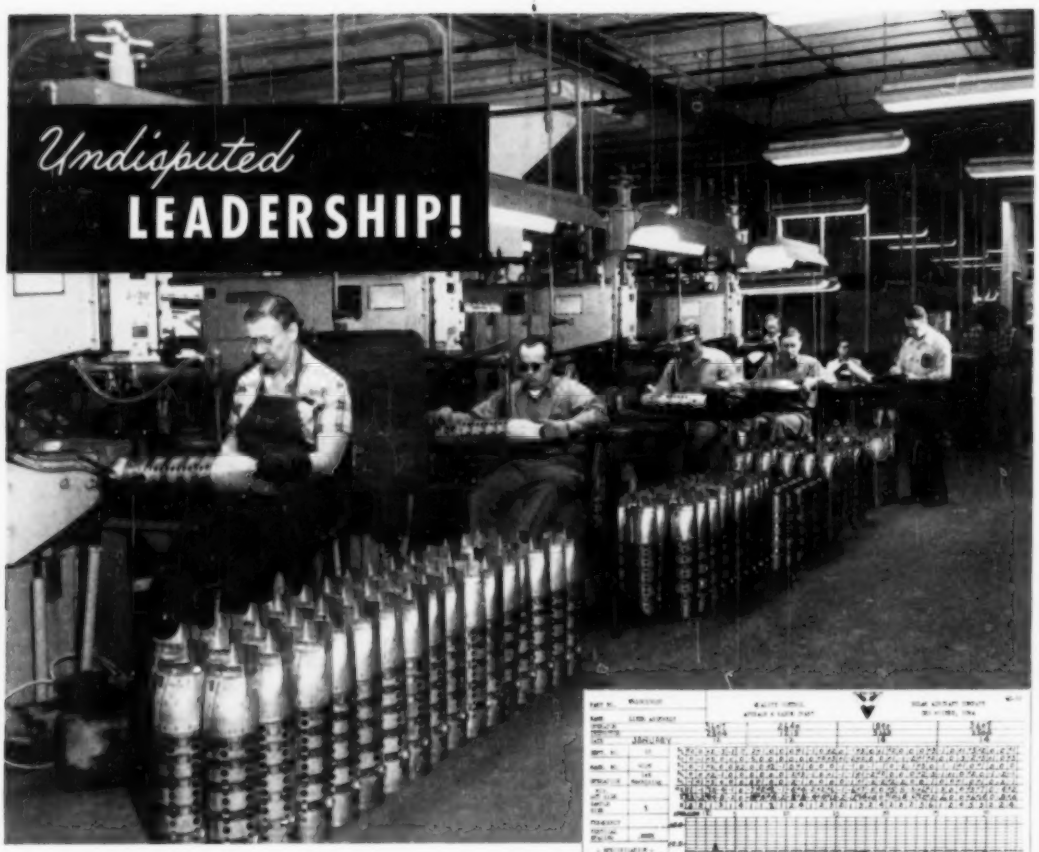
CUMMINS Diesel

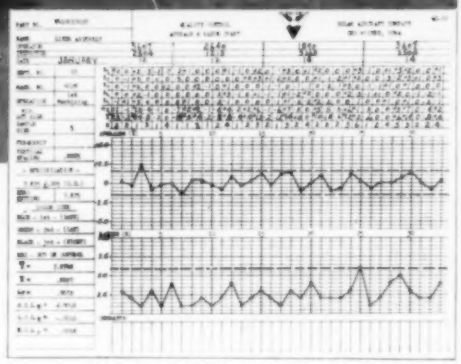
TRADEMARK REG. U. S. PAT. OFF.

Diesel power by CUMMINS

CUMMINS ENGINE COMPANY, INC., COLUMBUS, INDIANA

Export: Cummins Diesel Export Corporation • Columbus, Indiana, U.S.A. • Cable: Cumdiex





Undisputed
QUALITY!

QUALITY is the ingredient of a product or service that creates "*repeat business*". And it is the repeat business at Solar that marks it for leadership as a manufacturer of high-temperature components for jet and piston engines, afterburners, gas turbines, aircraft bellows and industrial expansion joints and ceramic coatings for high-temperature application. 1952 is Solar's 25th Anniversary of *repeat business* . . . business based on producing the highest quality obtainable through rigid inspection methods, including Statistical Quality Control.

(Copyright 1952)

SOLAR AIRCRAFT COMPANY

MIDWEST PLANT: DES MOINES 5, IOWA MAIN PLANT: SAN DIEGO 12, CALIFORNIA

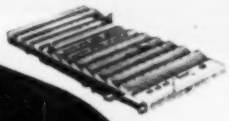
SOLAR 1927 1952

Kelsey-Hayes

Know How

...in DEFENSE and PEACE-TIME production

Kelsey Hayes

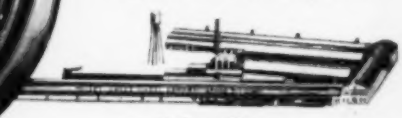


Kelsey-Hayes
Los Angeles, Cal. Plant

Kelsey-Hayes
Detroit, Mich., McGraw Plant

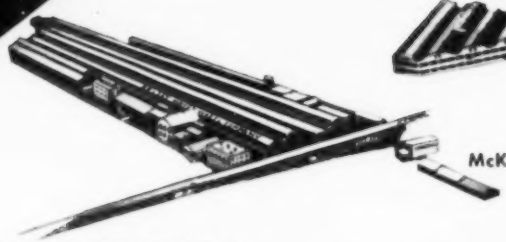
Kelsey-Hayes
Windsor, Ont., Canada Plant

Kelsey-Hayes
Detroit Mich., Military Plant



Kelsey-Hayes
Jackson, Mich. Plant

Kelsey-Hayes
Davenport, Iowa Plant



Kelsey-Hayes
McKeesport, Penna. Plant

FOR MILITARY AND CIVILIAN USE:

Wheels, brakes, hubs and drums for cars, trucks, tractors . . . and cargo trailers, troop carriers, gun carriages, tanks, etc.

Electric brakes, brake power equipment, power chambers . . . and valves for all types of military and civilian vehicles.

Shells and shell casings, rockets, and aircraft engine parts, etc.

KELSEY-HAYES WHEEL COMPANY
MILITARY AVE., DETROIT 32, MICHIGAN

PRECISION
...in Electronics

As the world's largest company devoted exclusively to *precision electronics and television*, Du Mont is proud of the QUALITY of its products. From incoming inspection of materials and components, through all stages of assembly and on to finished equipment, there is QUALITY CONTROL.

Typical of the 21 inspections controlling Du Mont Teletrons* is this operation with specially calibrated microscope. Du Mont transmitters, receivers and oscillographs are likewise checked and rechecked through all production stages.

Such is the meaning of QUALITY CONTROL to Du Mont, and consequently the meaning of Du Mont to quality-conscious buyers of electronic equipment.

DU MONT

ALLEN B. DU MONT LABORATORIES, INC.
With plants in East Paterson, Clifton and Passaic, N. J.

*Trademark of Du Mont TV picture tubes

NEW "ROCKET"! 160 HORSEPOWER!

—and

HYDRA-MATIC SUPER DRIVE!

1952 SUPER "88"

New "Rocket" Engine for new "Rocket" action! That's Oldsmobile's sensational power story for 1952! And yet, this great 160 h.p. "Rocket" would never exist—*could never exist*—without Oldsmobile quality control. The high standards of modern manufacture which this famous engine demands can only be met with a continuous, exacting quality control program. That's why the "Rocket" Engine and Oldsmobile's new Hydra-Matic Super Drive* are the top power team on the highway. Drive the new Super "88" or the Classic *Ninety-Eight* at your Oldsmobile dealer's—*and see for yourself!*

*Above, Oldsmobile Super "88" 4-Door Sedan. *Hydra-Matic Super Drive optional at extra cost. Equipment, accessories, and trim illustrated subject to change without notice.*

Product of General Motors

"ROCKET" OLDSMOBILE

OLDSMOBILE DIVISION • GENERAL MOTORS CORPORATION • LANSING, MICH.

Quality Control begins with Research

World's Largest Research Center for Building Materials and Asbestos Products—Manville, N. J.

Johns-Manville

- **Products of quality for 92 years**
- **Pioneers in quality control**
- **Manufacturer of 400 lines of products for home and industry**

Through the statistical approach to Quality Control, Johns-Manville is zealously maintaining its reputation for quality and passing on these benefits to its millions of customers.

JOHNS MANVILLE JM PRODUCTS

Johns-Manville

22 EAST 40TH ST. NEW YORK 16, N. Y.

Stud runouts reduced to .010!

Diversity of products and production calls for constant vigilance at International Harvester. Its Manufacturing Divisions, through their Quality Control Program, meet this day-to-day challenge because they are backed by a spirit of active cooperation from top management. This cooperation is also reflected in planning and tool design . . . by production and inspection supervisors . . . and above all, by the men in the shops who operate the machines.

Here is a typical example of how this aggressive program pays tremendous dividends and ensures finest quality products for our customers:

PROBLEM | Assembly difficulties with cylinder head studs indicated that trouble arose from excessive body runout in relation to thread axis, which resulted in the cylinder head gasket becoming damaged during assembly.

ACTION | All stock on hand was inspected. Studs with excessive runout were rejected. An X bar R chart, along with direct reading gauges, was placed on the job and data was gathered that indicated necessary equipment repairs.

RESULTS | Equipment repaired immediately. Consequently we are now able to *produce these studs with less than .010 runout!*

INTERNATIONAL HARVESTER

The confidence in IH products comes from the quality built into them.

tough jobs—EVERYWHERE
demand AMERICAN BOSCH performance

Hauling heavy loads through broiling desert heat and cold mountain passes is all in the day's work for many over-the-road truckers. Dependable, fast schedules are their stock in trade—and that's why you'll find American Bosch products on the job.

Many of the Diesel engines used to furnish the tremendous lugging power in these operations are equipped with American Bosch fuel injection systems—pumps, governors and nozzles that deliver the fuel . . . precisely timed and accurately metered to each engine cylinder, pressure atomized for maximum combustion efficiency.

Other American Bosch products, too, contribute to performance and safety—heavy duty generators and voltage regulators that furnish the required current for batteries and the numerous electrical accessories—electric windshield wipers that provide constant clear vision for drivers regardless of engine speed or load.

Over 40 years of pioneering design, precision manufacture and thoroughgoing service have built the American Bosch reputation for dependability in the toughest going. Continuous research, development and field engineering assure that this reputation will grow even stronger through the years. American Bosch Corporation, Springfield 7, Mass.

AMERICAN BOSCH

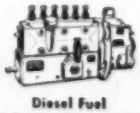
Automotive and Aviation Magnetos

Generators and Regulators

Components for Aircraft Engines

All Electric Windshield Wipers

Ignition Coils



Diesel Fuel Injection Equipment

- "Key instrument in inspection"
- "Protects quality prestige"
- "Customers' rejections less than 1/50 of one per cent"
- "Saves from $3 to $5 per hour"

Photo Courtesy of Modern Corp., Detroit, Mich.

Modern Corporation, Detroit, Mich., manufacturer of fine MODCO cutting tools, says this about their new 30-inch J & L Comparator:

"Modern Corporation's new 30-inch J&L Comparator has become the key instrument in the inspection of fine MODCO tools. Its size enables the inspector to examine the complete contour of most tools, without transfer of reference points, and thus without the chance for human error to creep in.

While the primary reason Modern Corporation bought the Comparator was to promote inspection accuracy, it is showing an important cost saving: Every time the J&L Comparator is used, it saves from three to five dollars per hour, depending on the tool under inspection!"

This instrument is one of 14 J & L Comparators in the Modern Corporation plant, and the largest.

P.S.

Jones & Lamson Comparators guarantee swift, sure QUALITY CONTROL— *throughout your production lines.* Write for Catalog No. 402. One of our eleven models will fit your needs.

JONES & LAMSON

JONES & LAMSON MACHINE COMPANY
Springfield, Vermont, U. S. A.

Machine Tool Craftsmen Since 1835

COMPARATOR DIV.
Dept. 710

Jones & Lamson Machine Company
Springfield, Vermont, U. S. A.
Please send Comparator Catalog No. 402.

NAME _____ TITLE _____

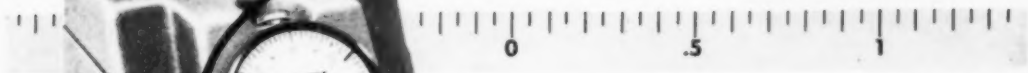
COMPANY _____

STREET _____

CITY _____ STATE _____

Only DIMENSIONAIR Gives You All This

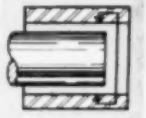
FULL 7½" SCALE OF CALIBRATED ACCURACY



All of it measures accurately. Not just part of it!

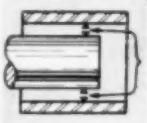
LONGER APPROACH RANGE

You measure earlier BEFORE reaching minimum work size. Less scrap. Same plug used on both rough and finished dimension. Total minus range .0015".



GREATER CLEARANCE (.0018" up to .0038")

You can read Undersize, Taper, Out-of-Round and Irregular Shape Holes without plug getting stuck. Easier to insert plug.

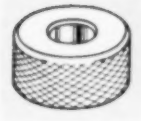


STAY-PUT ZERO — DON'T WORRY ABOUT PRESSURE FLUCTUATIONS

They do not affect accuracy. Set zero when you start—that's all. No drifting. Full Jeweled Cushioned Movement — more sensitive to size variations.

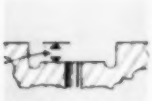
10 SECOND SET-UP — JUST ONE ADJUSTMENT

As simple as setting a Dial Indicator. Direct and Positive.



ONE MASTER ONLY — FORGET THE IDEA TWO ARE NEEDED

Only air gage with enough precision to permit use of only one master. Interchangeable plugs — every plug calibrates on same scale.

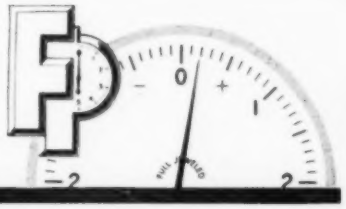


LONGER PLUG WEAR — JET FACES ARE DEEPER

Saves you real money.

Try it — and prove it to yourself

Only the Dimensionair provides the many important features above. Customers who have given the Dimensionair a thorough trial have found its advantages outstanding and have ordered many Dimensionairs in large quantities, and repeatedly. We invite you to try the Federal Dimensionair and compare it with any other air gage. Ask our nearest representative or write today for complete information and prices. FEDERAL PRODUCTS CORPORATION, 1155 Eddy Street, Providence 1, R. I.

FEDERAL

Largest manufacturer devoted exclusively to designing and manufacturing *all types* of DIMENSIONAL INDICATING GAGES